



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



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the urban big data lab

香海論壇——文化遺產的建模與可視化探索

# 數字遺產保育中的空間信息技术

## Digital Heritage Conservation With Spatial Information Technologies

Anthony GO Yeh, Fan Xue

Faculty of Architecture, University of Hong Kong

國家文物局“空間信息技术”基地 - 港珠澳工作站（港大）

25 Jul 2024





# 0 The HZM Station (HKU)



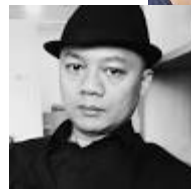
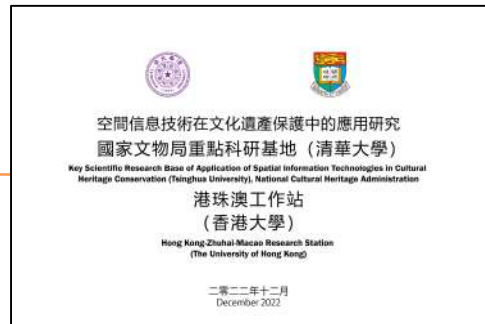
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## ◆ 國家文物局“空間信息技術”重點科研基地（清華大學）

- ▣ 通過空間信息技術在文化遺產保護中的應用研究，全面強化文物科技創新，推進文物領域交叉學科建設，加強建築遺產保護研究力量，為中國特色的建築遺產保護奠定理論基礎。

## ◆ 港珠澳工作站（香港大學）

- ▣ 該工作站的研究以大灣區嶺南及港澳特色文化遺產為研究對象，由葉嘉安院士作為總召集人，綜合發展面向數字遺產文物保護的空間信息技術。<https://smarterheritage.hku.hk/>
- ▣ Team from all the departments:
  - Director: Prof Anthony Yeh (DUPAD),
  - AD: Frank (REC),
  - Members: Kasing (REC), Katherine (REC), Linda (DLA), Bin (DLA)





# 0 My background



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◆ Xue, Fan (Frank)

◆ Edu. background

2004 □ BEng in **Automation**

2004 □ MSc in **Computer Science**

2007 □ PhD(\*PolyU) in **System Engineering**

2013 □ PDF\*/RAP/AP/AssocP in **Construction IT**

◆ Research interests

□ Urban sensing and computing

□ As-built BIM and Digital Twin

□ Automation/IT in construction

□ Operations research, ML

□ Blockchain applications in construction

◆ Professional

□ MACM, MHKGISA, MIEEE, SMC GS, MASC, MISDE

□ Vice-Chair ACM-HK, Com. CGS-BIM, Com. ASC-SC

□ Engineering panel of RGC APSF

◆ 16M grants, >100 papers, 30 awards

◆  ESI Top 1% Researcher

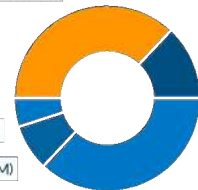
◆  World Top 2% Scientist

HK RGC (\$5.4M)

GDST (\$0.6M)

SZSTI (\$1.3M)

ITF (\$6.2M)



The background of the slide features a faded, artistic rendering of a grand, classical-style building. The building has a long facade with a series of columns and a prominent tower on the right side. In the foreground, there are lush green and reddish-brown plants, possibly palm trees and other tropical foliage, which are also rendered in a soft, painterly style. The overall color palette is light and airy, with a focus on greens and earthy tones.

Section 1

# **INTRO TO DIGITAL HERITAGE CONSERVATION**



# 1 Case of existing: *Notre-Dame of Paris*



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- ▣ UNESCO world heritage site
- ▣ A fire in 4/2019
  - Last time 1789
- ▣ Reopens in 12/2024



(Src: WaPo staff)



Notre-Dame: building a digital twin | CNRS (<https://youtu.be/p-2J0H5i6-4?si=kBdSDweN0adD9Hc7&t=141>)



# 1 Case of hidden: Finding a Viking ship, Norway



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(Source: NIKU Norway, <https://www.youtube.com/watch?v=RXZNk3R8YKU> )

◆ Gjellestad ship in GPR scans in 2018

- ▣ By NIKU (Norwegian Institute for Cultural Heritage Research)
- ▣ Excavated in 2021



(Source: Science Norway, <https://www.sciencenorway.no/archaeology-viking-age-vikings/archaeologists-sound-the-alarm-urgent-action-needed-to-preserve-the-gjellestad-ship-remains/2382363> )



# 1 Case of gone: 张家湾 “京杭大运河第一码头”



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(Source: Guangzhou OkayGIS 2022, our partner)

◆ 1920-50s historical city model restored

▣ Drone + old photos





Section 2

# **SOME OF OUR SPATIAL TECHNOLOGY APPLICATIONS**





# 2.1 HK Tram Trail (& HKU 100)



## ◆ Hong Kong Tramways

- ▣ *A.k.a. Ding Ding*
- ▣ 120 years in 2024
- ▣ Lively and vibrant cultural heritage
- ▣ GPS story App by Yeh (2011)



Xue: Digital heritage. Jul. 2024.

2011

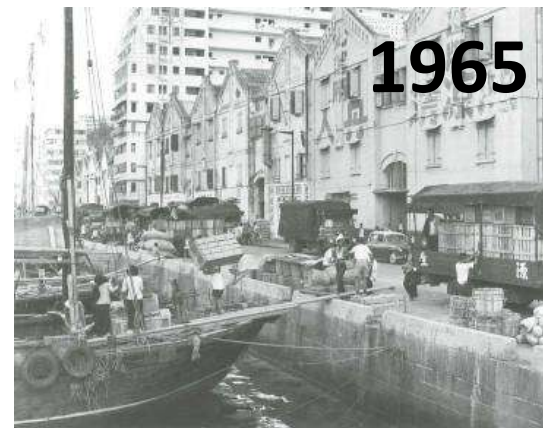
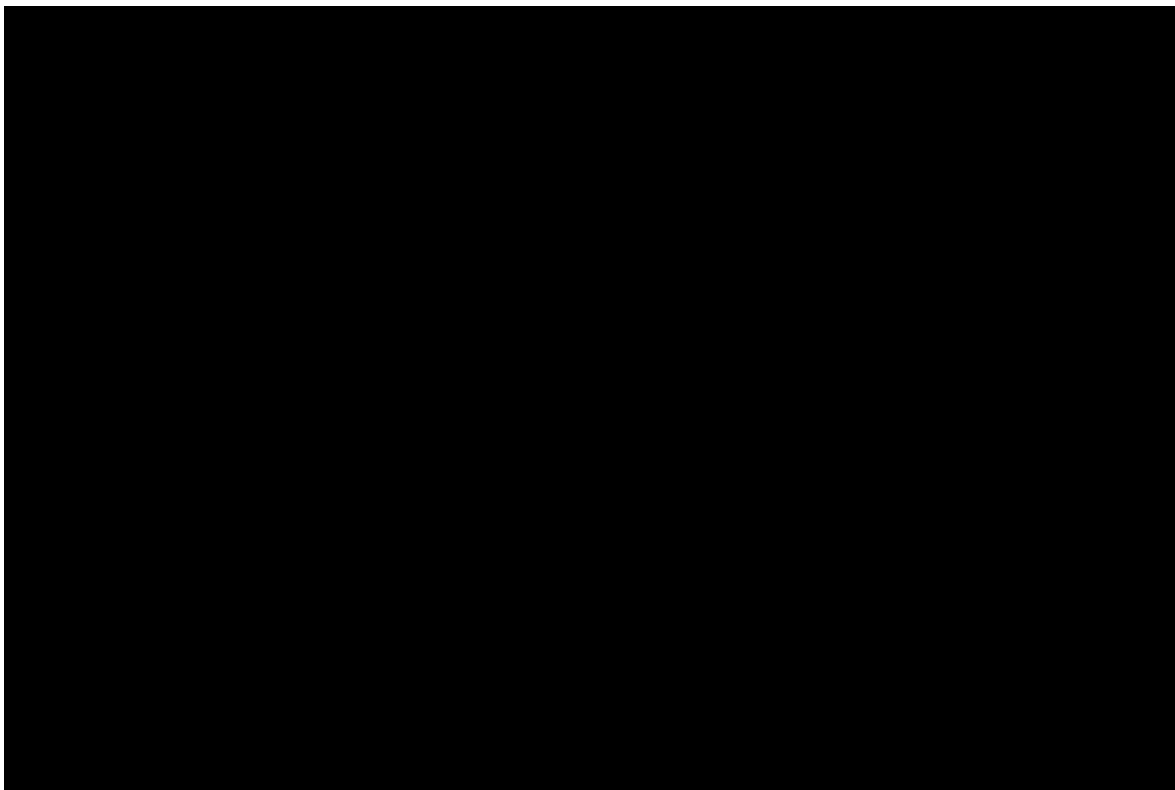
The screenshot shows a web browser window with the URL `dupad.hku.hk/cusup/tram/put/index.html`. The page title is "Hong Kong Tram Trail – 100 Years of Urban Development" and "香港軌跡 – 百年城市發展". It features a historical map of Hong Kong with tram routes, a "PROGRESS DIAGRAM", and several images of trams and people. A yellow box in the top right corner of the browser window indicates the year "2011".



## 2.1 HK Tram Trail (& HKU 100)



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## 2.2 360 Virtual tour (with story)



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The screenshot shows a web browser window displaying the website for the Hong Kong Diocesan Building and Development Commission's 360 Virtual Church Tours. The browser's address bar shows the URL <https://dbdc.catholic.org.hk/RDC/home/tc/index.html>. The website header includes the text "天主教香港教區建築及發展委員會 - 360虛擬聖堂導覽" and "Hong Kong Diocesan Building and Development Commission - 360 Virtual Church Tours", along with navigation links for "關於我們" and "聯絡方法". The main content area features a section titled "介紹" (Introduction) with a paragraph explaining the project's purpose and a list of featured virtual tours under the heading "360虛擬聖堂導覽". The list includes: 聖母無原罪主教座堂, 聖若瑟小堂, 聖母聖衣堂, and 聖神修院.

360聖堂虛擬導覽

https://dbdc.catholic.org.hk/RDC/home/tc/index.html

中文 | English

天主教香港教區建築及發展委員會 - 360虛擬聖堂導覽  
Hong Kong Diocesan Building and Development Commission - 360 Virtual Church Tours

關於我們 聯絡方法

### 介紹

《360虛擬聖堂導覽》是天主教香港教區建築及發展委員會的研究與發展委員會於2018年暑假開始建立的，目的是讓天主教徒和遊客們能夠在實地到一個天主教的聖堂前，能夠在網上進行《360虛擬聖堂導覽》，詳細瞭解該聖堂的建築、文物和歷史。目前，我們已經建立了7個《360虛擬聖堂導覽》。我們希望更多聖堂能參與製作，讓我們能夠建立更多的《360虛擬聖堂導覽》。如欲參與《360虛擬聖堂導覽》的製作，請聯繫香港堅道16號，天主教教區中心901室教區建築與發展委員會，電子郵件：[dbdc@catholic.org.hk](mailto:dbdc@catholic.org.hk)，電話：(852) 2526 3200。

### 360虛擬聖堂導覽

-  聖母無原罪主教座堂
-  聖若瑟小堂
-  聖母聖衣堂
-  聖神修院

[https://dbdc.catholic.org.hk/RDC/001\\_CathedralofImmaculateConception/church360\\_chin/church360/index.html](https://dbdc.catholic.org.hk/RDC/001_CathedralofImmaculateConception/church360_chin/church360/index.html)



dbdc.catholic.org.hk/RDC/001\_CathedralofImmaculateConception/church360\_chin/church360/index.html

中文 | English

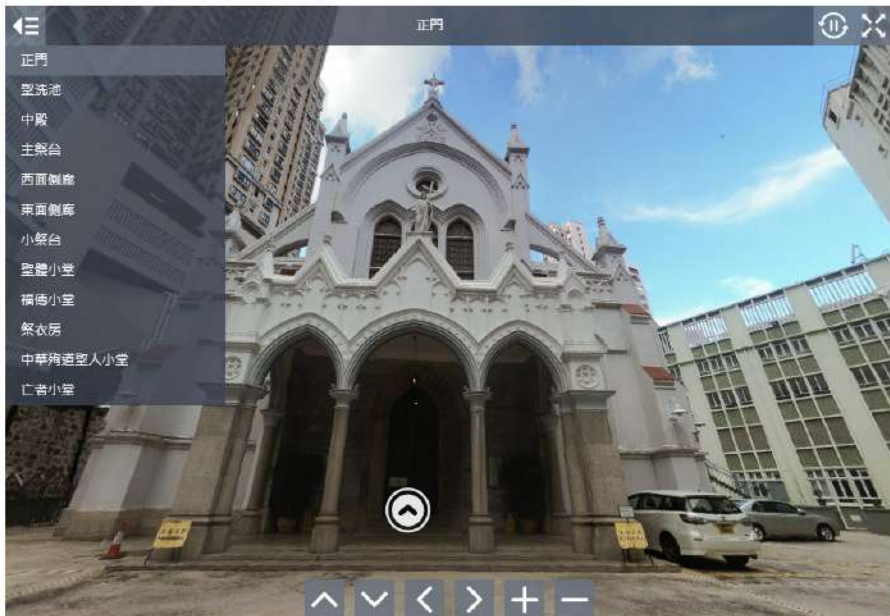
天主教香港教區建築及發展委員會 - 360虛擬聖堂導覽  
Hong Kong Diocesan Building and Development Commission - 360 Virtual Church Tours

關於我們

聯絡方法

### 聖母無原罪主教座堂

360°日景 360°夜景 文物 平面圖 地圖



360°日景



## 聖母無原罪主教座堂

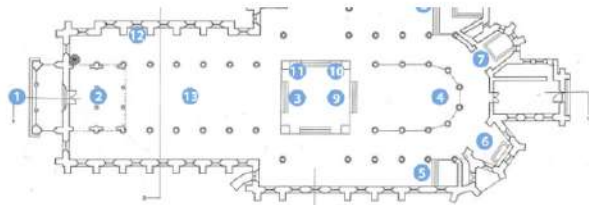
360°日景

360°夜景

文物

平面圖

地圖



可按圖示進入360全景遊覽

文化遺產委員會

最初，聖母無原罪堂在1842年建於牛欄峇魯碼頭，聖堂在1859年遭德律風公司大火焚毀，夷為平地。聖堂在1860年重建，後來因為鄰近地塊不宜作為教會聚會地點，加上教友人數不斷增加，當時香港首任代牧高主教決定另建聖堂，故於1881年購入堅道地塊繼續興建的主教座堂，而舊時的聖堂於1880年被專家購買後拆卸。現時的主教座堂於1888年12月7日至在無原罪節日前夕舉行首次的獻堂。

### 主教座堂概略



#### 1. 正門

透過正門，我們與天主相連。耶穌說：「我就是門，誰若經過我進來，必得安全。」

[按此進入360全景遊覽](#)



#### 2. 聖洗池

位於正門入口處，是入門聖堂的第一步，人經過水和聖神而重生，成為天主的子女。

[按此進入360全景遊覽](#)



#### 3. 主祭台

是舉行彌撒的祭具，象徵著全體信友在基督內的團結和團結。

[按此進入360全景遊覽](#)



## 2.2 Pokfulam Conduit (story, mockup)

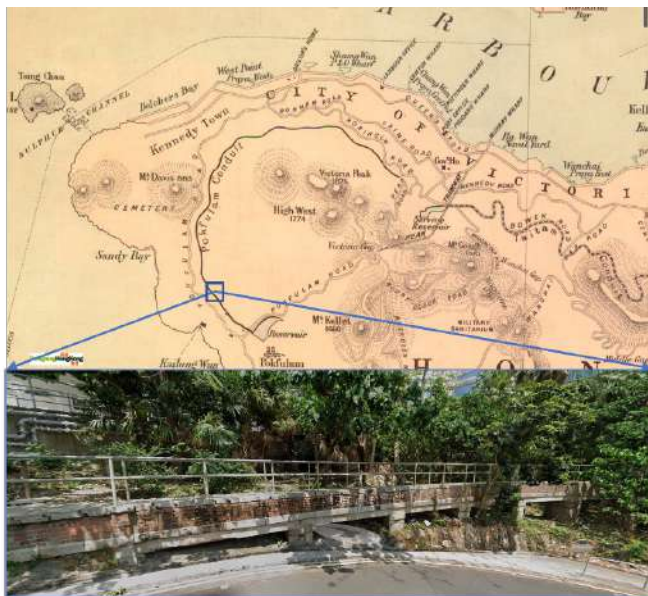


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◆ Pokfulam Conduit (Built 1876-77), now a hiking trail

▣ VR-ready web GIS <http://147.8.124.72:8080/vrtour/canal/>

▣ Unity 3D <https://play.unity.com/mg/other/webgl-builds-217561>



A project collaborated with Dr Katherine Deng and Dr S.W. Poon



## 2.4 长城 镇北台



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### ◆ 镇北台

- ▣ “万里长城第一台”
- ▣ 陕西省榆林市
- ▣ 全国重点文物保护单位 – No. 5-442
- ▣ By drone + Luma AI. DEMO (NeRF + webGS)
  - More accurate than traditional photogrammetry



Src: Author (2024). <https://lumalabs.ai/capture/55b74e2c-59b5-4fc2-9c0b-73317315612b>

The background of the slide features a classical building with a prominent tower on the right side. The building has a series of columns and arches. In the foreground, there are several palm trees and other tropical plants, some with reddish-brown foliage. The overall scene is brightly lit, suggesting a sunny day.

Section 3

# **AUTOMATING 3D MODEL RECONSTRUCTION**





# 3.1 A general workflow of Scan-to-BIM/CIM



◇ In 4 steps

1.1 Point-level

1.2 Primitive-level

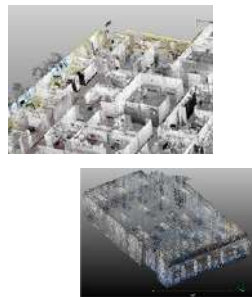
1.3 3D BIM details

2. BIM/CIM Applications

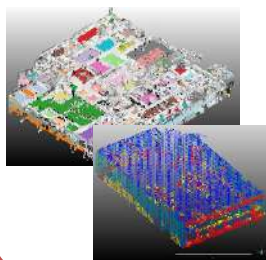
◇ Error metrics differ quite a lot

▣ Between steps

Input 3D scan

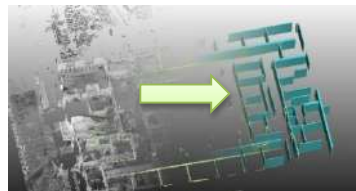


1.1 Segmentation

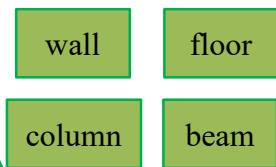


Time cost: ~5%

Point-level (0D)

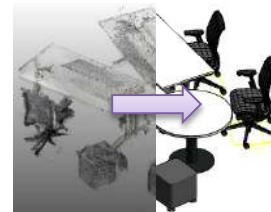


1.2 General architectural elements (AEs)

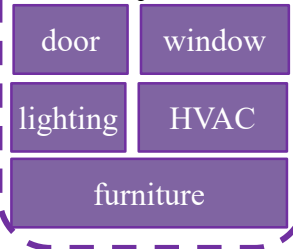


Time cost: ~20%

primitive-level (2.5D)



1.3 Detailed BIM objects

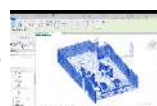


Time cost: ~75%

object-level (3D)

2. BIM/CIM applications

BIM/ Open-BIM



CIM



system-level (nD)

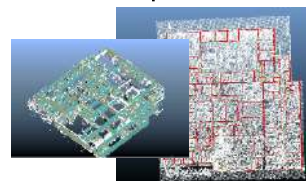
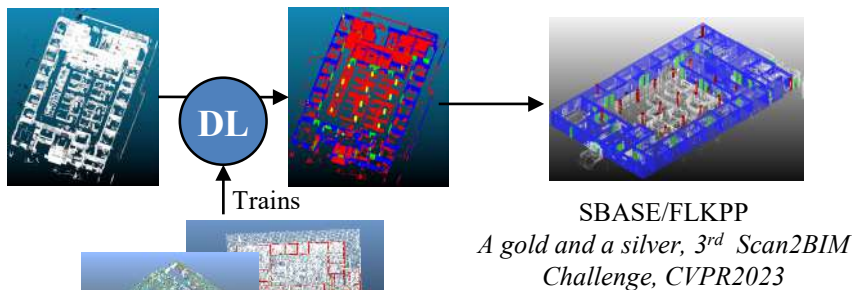
(Src: CV4AEC, Authors, Xue et al. 2019)  
Xue: Digital heritage. Jul. 2024.



# 3.1 Point-level classification (Wu et al, 2023; Li et al. 2023)

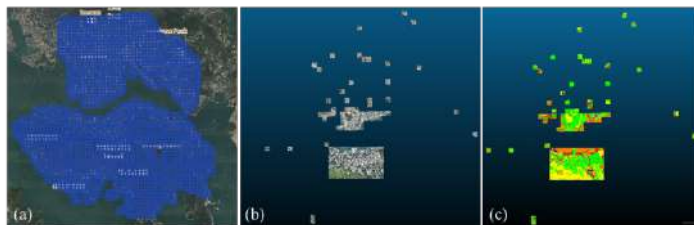
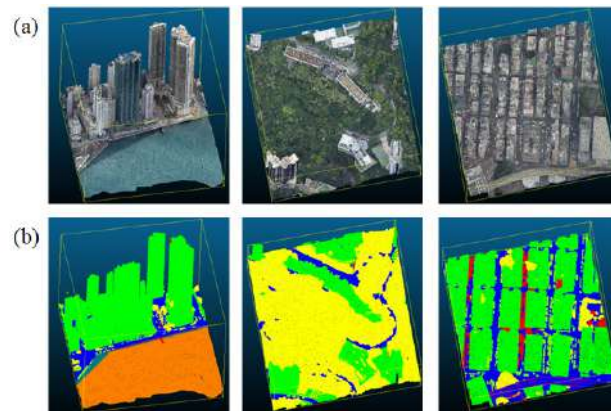


- ◇ E.g., supervised Deep learning
  - ▣ Adds a ‘label’ to each point
    - “Wall”, “columns”, “tree”...
  - ▣ Point-level semantics
- ◇ A high-rise high-density dataset
  - ▣ 150 tiles of HKI and KLN
    - From LandsD/PlanD’s city model
  - ▣ Sampled and annotated for city objects
  - ▣ To be open-sourced soon



An HRHD urban dataset (Li et al. 2023)

Supports





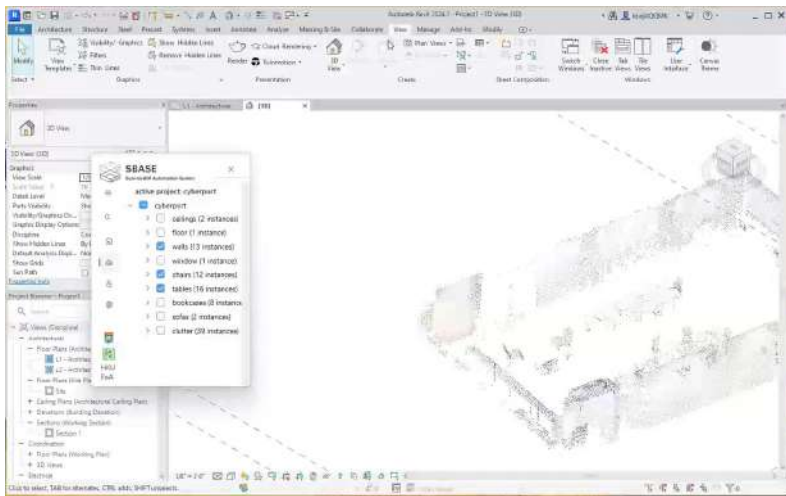
# 3.2 2.5D general AEs



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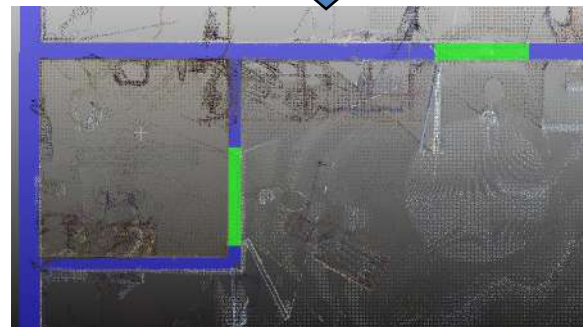
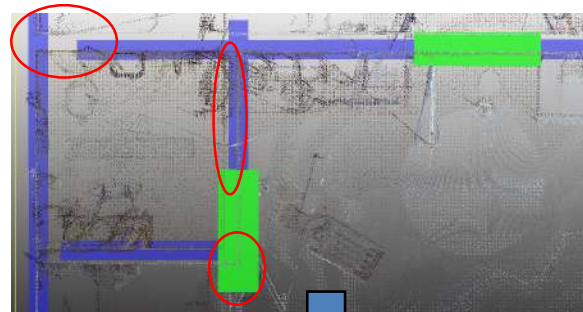
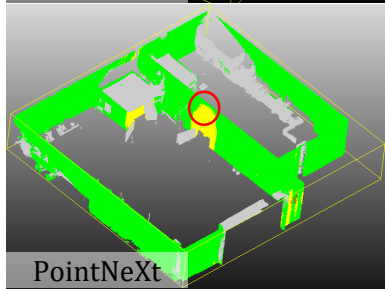
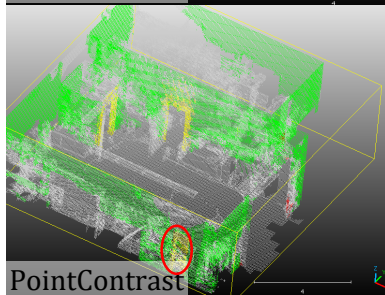
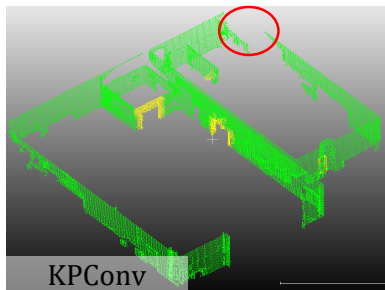
◆ Either manual or region growth

▣ Collusion adds new errors



Manual modelling with point segmented. Src: Author (2024)

Xue: Digital heritage. Jul. 2024.



Tested with Scan-to-BIM Challenge, CVPR2023/24  
Point-level mIoU: > 0.82  
Object-level mIoU ~ 0.45  
Src: Wu et al (2023a)

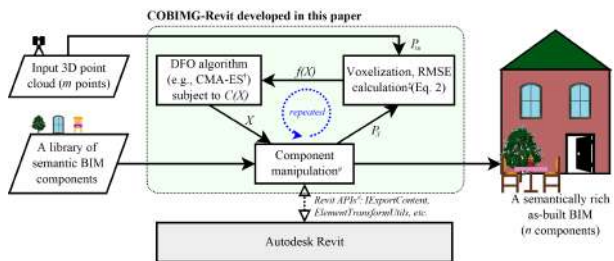


# 3.3 Similarity for registering 3D objects (Xue et al. 2016; 2019b)

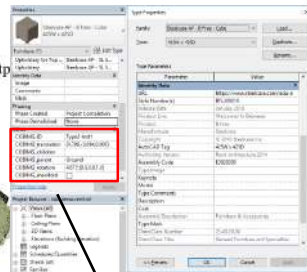


◇ Time = 6.44s (Manual = 300s), RMSE = 3.87 cm

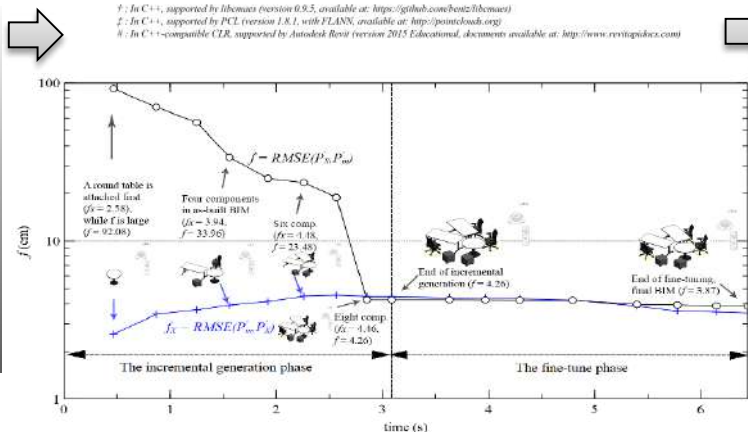
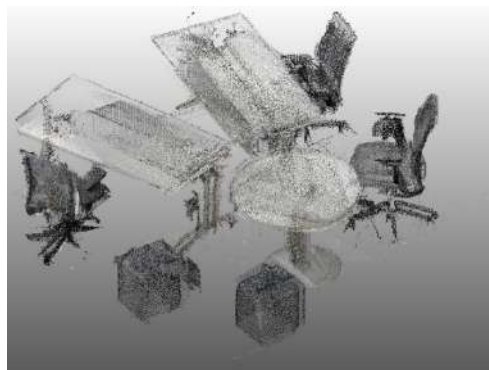
◇ (Class = Furniture)



(a) A screenshot of the 3D view of the output BIM



(b) A visual comparison between the input (grey points) and the output BIM



<sup>1</sup>: In C++, supported by libsvm (version 0.9.5, available at: <https://github.com/benji/libsvm/>)  
<sup>2</sup>: In C++, supported by PCL (version 1.8.1, with FLANN, available at: <http://pointclouds.org>)  
<sup>3</sup>: In C++, compatible CLR, supported by Autodesk Revit (version 2015 Educational, documents available at: <http://www.revitguides.com>)

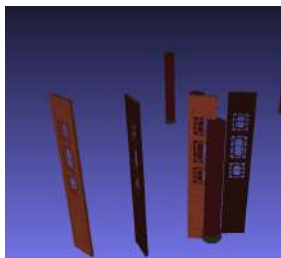
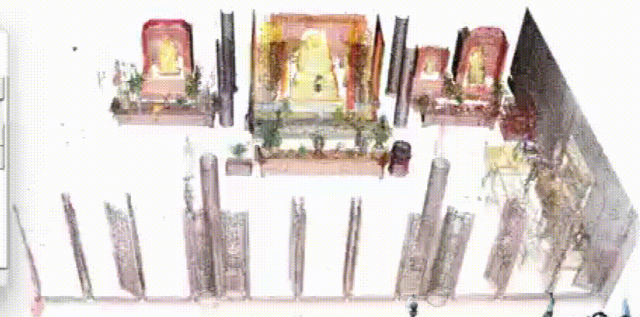
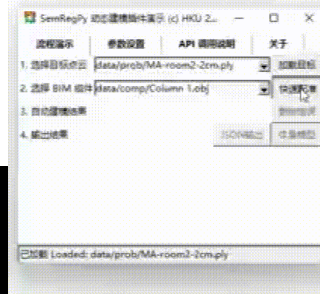


# 3.3 Applications to office and heritage DT



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Fitting BIM objects for location, rotation, and relational semantics (Xue 2019)



Fitting 3D columns for a timber architecture (廣州梅庵, Source: OkayGIS)



## 3.4 Clustering using 3D skeletons



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### ◆ Bronze drums (Lu et al., 2020)

- ▣ Spiritual, sacrifice, and musical instruments
- ▣ Across South China and Southeast Asia since 700s BCE
- ▣ Traditional storage: buried in soil (now >2,400 conserved)
- ▣ 8 types 八大類型 ( 萬家壩、石寨山、冷水沖、北流等)

### ◆ Decorative bronze frogs have more diversity 細節更多樣

- ▣ A variety (design, size, materials) evolved over time
- ▣ “bronze drums often unearthed in Guangxi by the tillers ... with a perfect circle with bent body ... five sitting frogs, each with a baby on its back.” (Zhou 1187) 周去非 (宋) 《岭外代答》
- ▣ “surrounding frogs indicate [the chief’s] title; the more frogs, the more honorable title.” (Zhu 1948) 朱昌奎 《宾阳县志·铜鼓考》



Discovery of a 2,000-yr drum in Guangxi, on 25 May 2023  
(Photo src: news.cn)





# 3.4 Clustering using 3D skeletons



iLab

## ◆ Cases: 铜鼓蛙饰

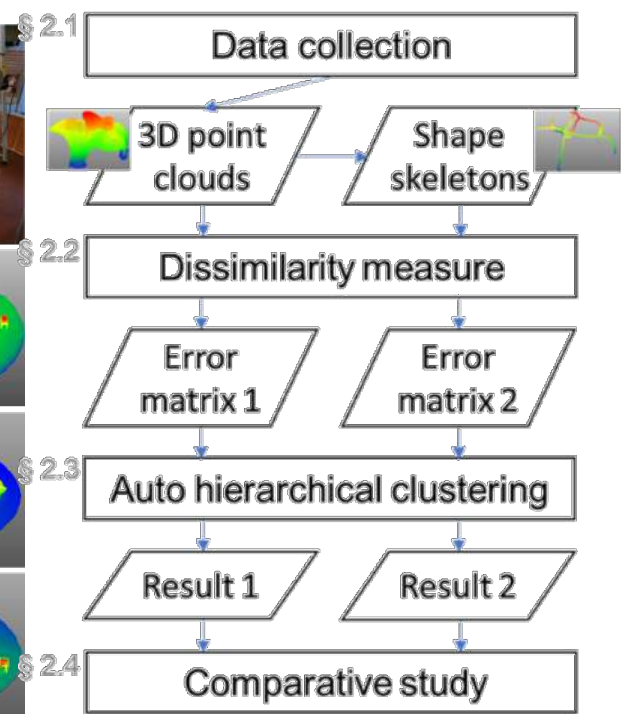
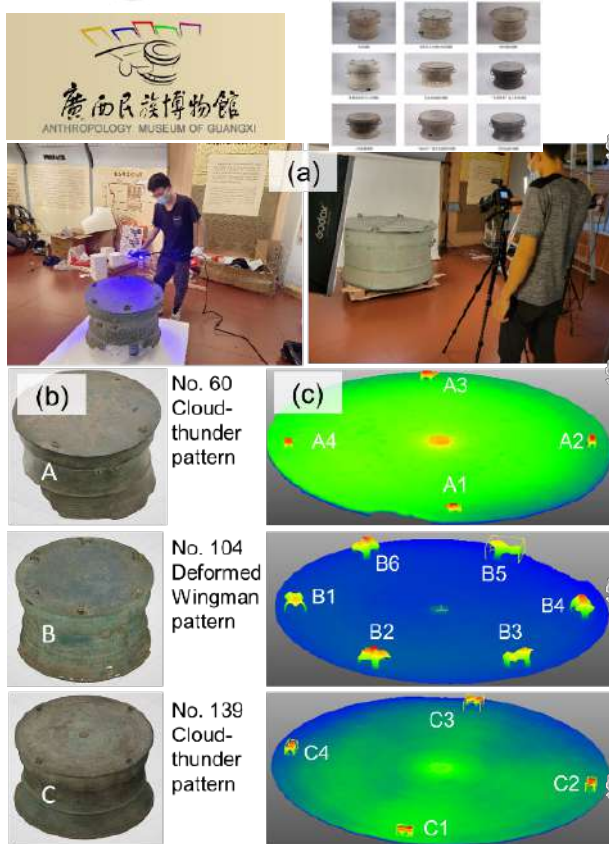
- ▣ 3 types, 14 frogs

## ◆ Objectives

- ▣ Grouping similar (Auto detect defects)
- ▣ 3D shape skeleton

## ◆ 3 steps

- ▣ Dis-similarity
- ▣ Auto Clustering (e.g., Covid-family tree)
- ▣ Comparison





# 3.4 Clustering using 3D skeletons



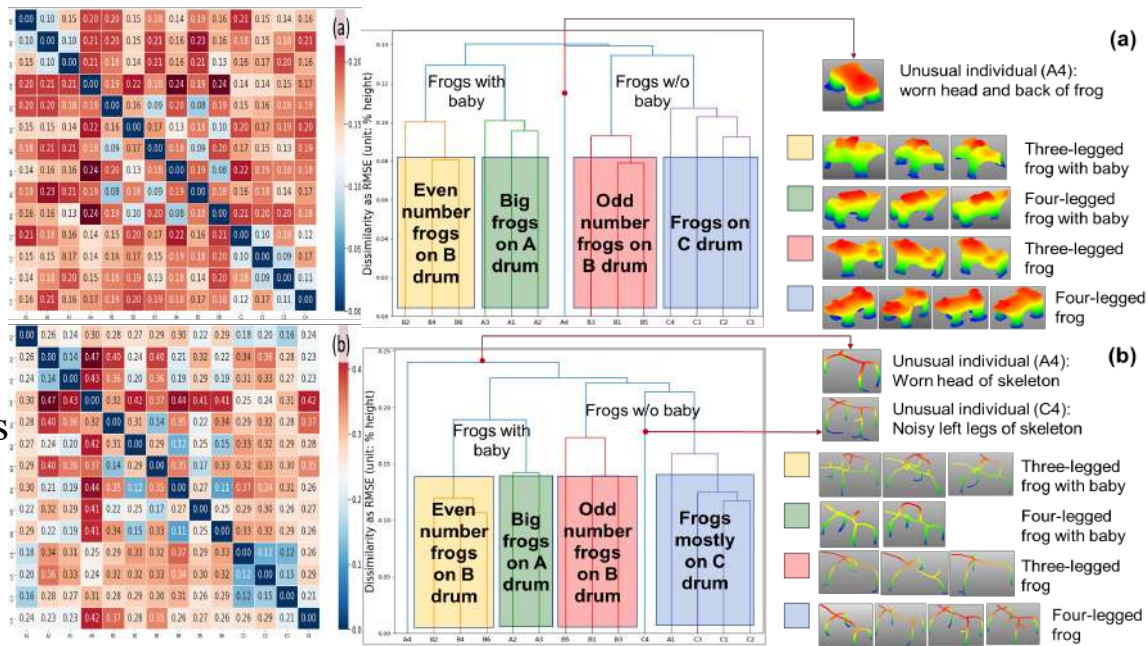
Both surface points & shape skeleton

- Similar patterns
- $\max_{ske} / \max_{sur} \approx 2$

Clustering (Obj. #1)

- Four groups in both
- Reflecting the style
- In line with the instruments and shape groups
- Outlier (damaged) highlighted automatically

A “family” tree of all frogs







# 3.4 Clustering using 3D skeletons

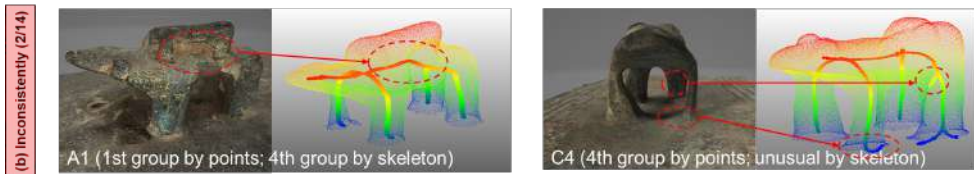
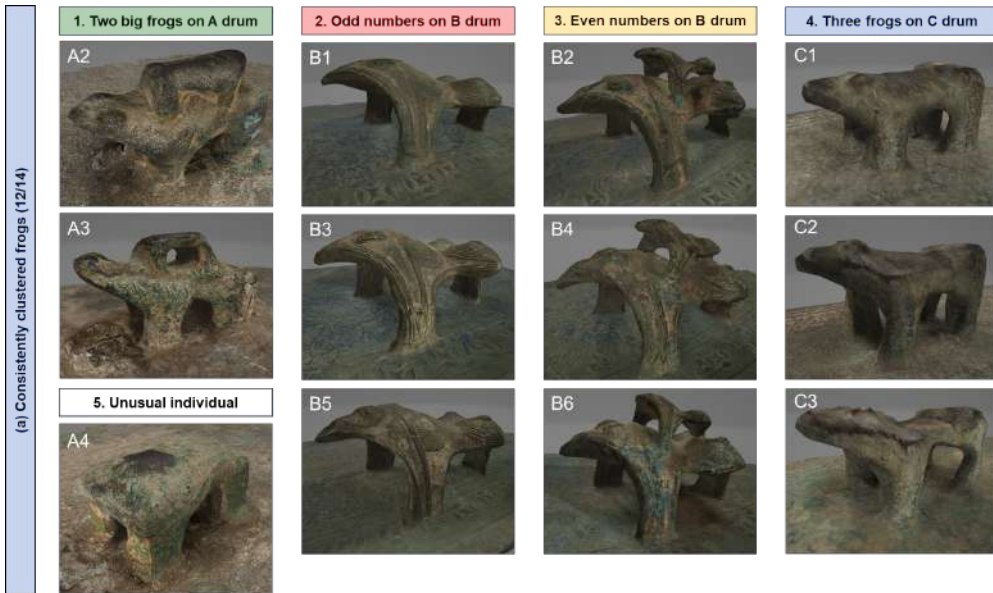


iLab

## ◆ Comparative results (Obj. #2)

- ▣ Same for 12 out of 14 ✓
- ▣ Assuming 3D surface grouping was true, the metrics of skeleton were: Precision = 0.850, Recall = 0.883,  $F_1 = 0.866$
- ▣ 2 inconsistencies due to: **limited presentation** of traditional (inscribed ball) skeleton in CGAL

		Group using shape skeleton				
		I	II	III	IV	V
Group using surface point clouds	I. Three-legged with baby	3				
	II. Four-legged with baby		2		1	
	III. Three-legged			3		
	IV. Four-legged				3	1
	V. Unusual					1





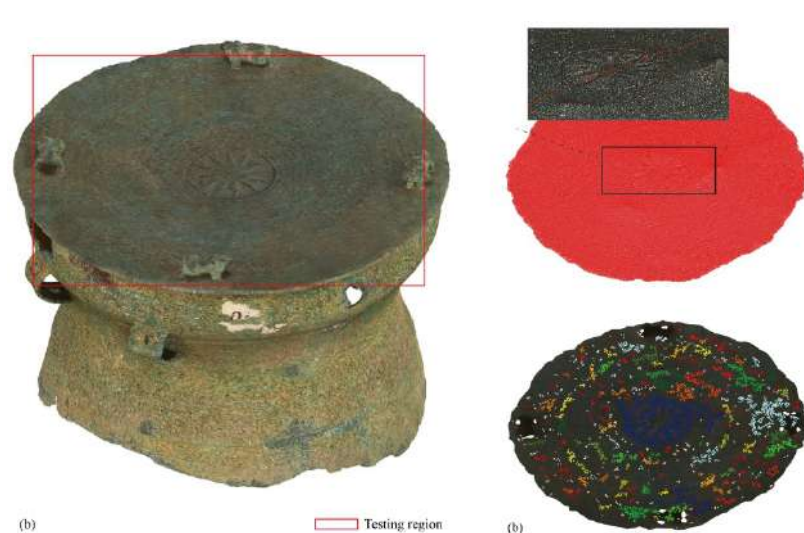
# 3.5 Texture segmentation



◆ Suitable cases: Textures on a surface

▣ As carving/casting

◆ Cases: 广同会馆、广西铜鼓



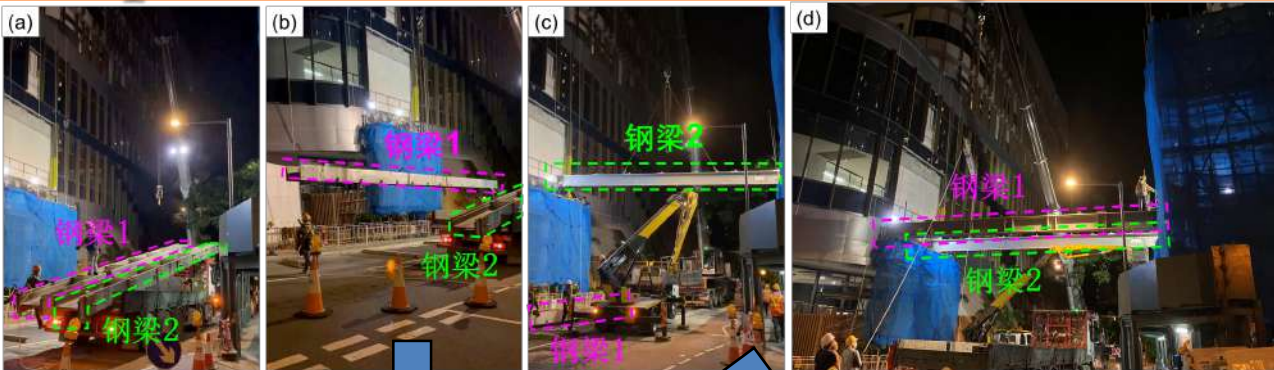
初步計算過程: (1) NURBS 擬合 + (2) 邊緣檢測 + (3) DBSCAN 臨近聚類 (Meng et al. 2023)



# 3.6 4D point cloud for streaming actions

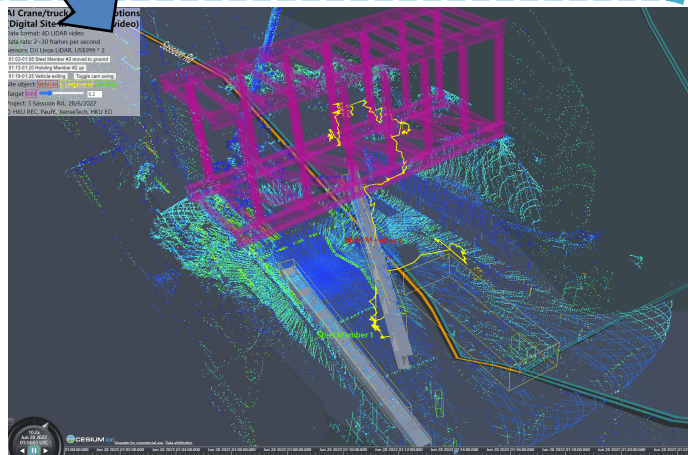
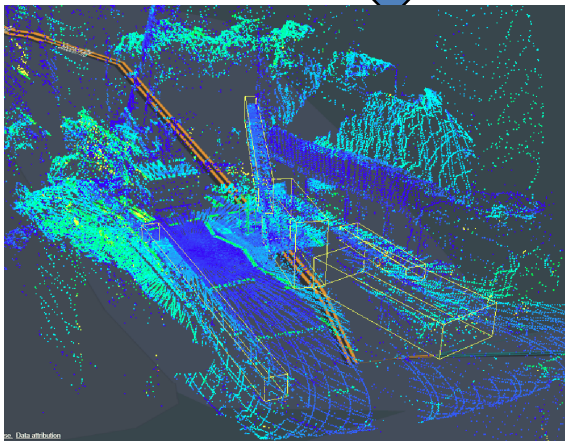


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- ◆ Fine motions
- ◆ For some intangible heritage ?
- ◆ Demo  
[http://147.8.124.72:8080/vr\\_tour/SassoonRoad/dt.html](http://147.8.124.72:8080/vr_tour/SassoonRoad/dt.html)

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Section 4

# SUMMARY

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# 4 A recap

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iLab

- ◆ Digital model
  - ▣ Very useful for cultural heritage conservation
  - ▣ No matter existing, hidden, or gone
- ◆ Spatial information technology
  - ▣ Vital data source for digital heritage
- ◆ Auto modeling of 3D points
  - ▣ Point-level, object-level
- ◆ Limitations
  - ▣ A huge gap between point-level and object-level detection
  - ▣ Low automation level
- ◆ New opportunities like 3DGS/4DPC





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iLab

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  - ▣ HK ITC (ITP/004/23LP)
- ◆ Courtesy by Prof Yeh and OkayGIS
- ◆ Students' works involved or cited
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  - ▣ Yijie Wu
  - ▣ Siyuan Meng
  - ▣ Dong Liang
  - ▣ Sou-Han Chen

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*Thank you!*

**Q&A**

