TITLE

Surface or skeleton? Automatic hierarchical clustering of 3D point clouds of bronze frog drums for heritage digital twins

AUTHORS

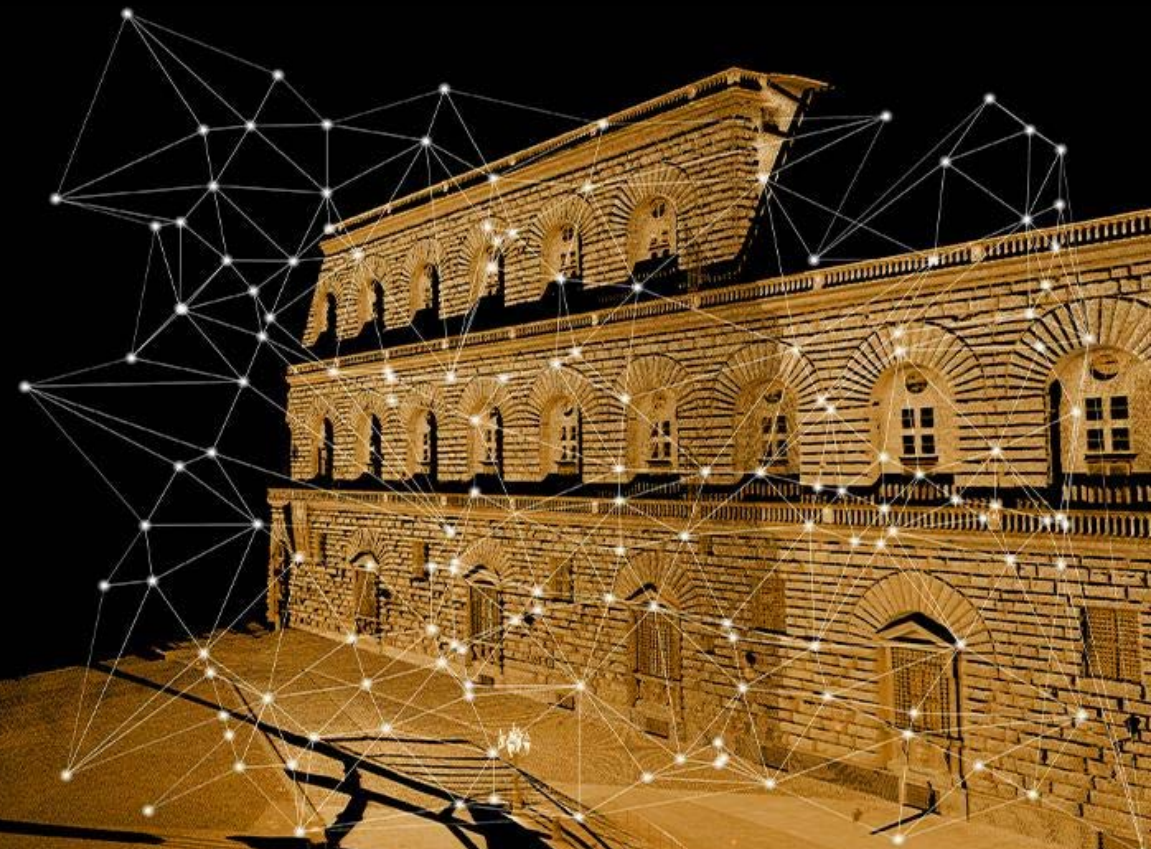**Fan Xue[1]***, Wenjin Zhang[2], Guangji Xu[3],
Qianyun Zhou[1], Yijie Wu [1]

* xuef@hku.hk

AFFILIATIONS

[1] The University of Hong Kong
[2] Guangzhou Okay Information Technology Ltd.
[3] Anthropology Museum of Guangxi

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Humanities and Digital Technologies for Shaping the Future

MATERIALS

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)

Decorative bronze frogs
- 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)
- "surrounding frogs indicate [the chief's] **title**; the more frogs, the more honorable title." (Zhu 1948)
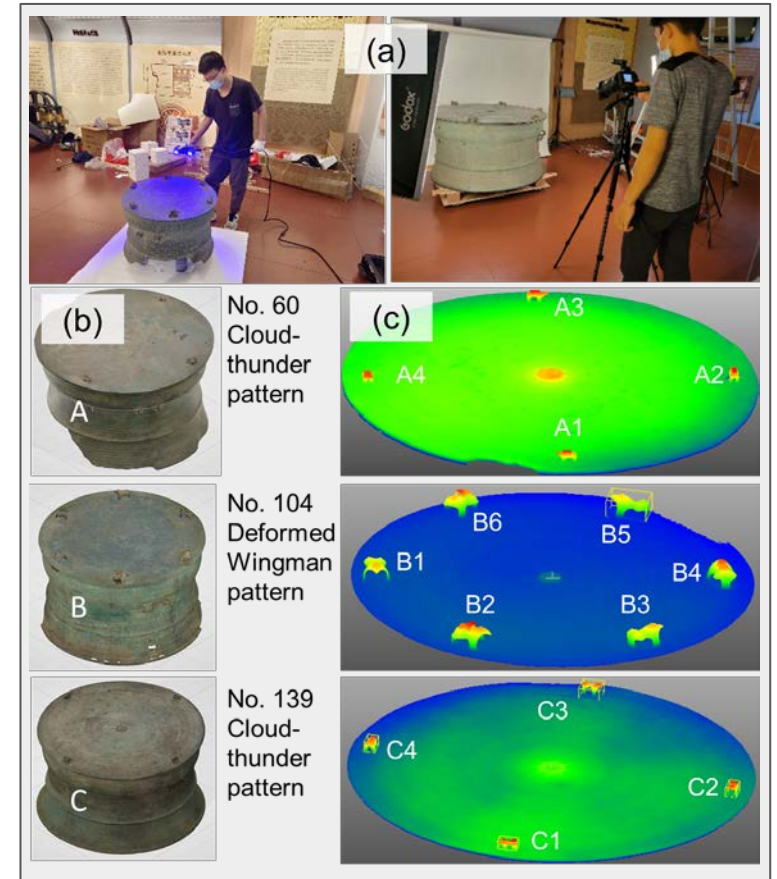
Discovery of a 2,000-yr drum in Guangxi, on 25 May 2023
(Photo src: news.cn)


A1 B1 C1

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AIM AND METHODS

Objectives

- To **understand** the 3D details of bronze frogs using clustering for heritage digital twin
- To **compare** 3D surface and skeleton (abstract, topology-aware, light-sized) as source of clustering

Methods in 4 steps

- Data curation (skeletonization using CGAL)
- Geometric dissimilarity matrix (Xue et al. 2020)
- Unsupervised hierarchical clustering (auto threshold)
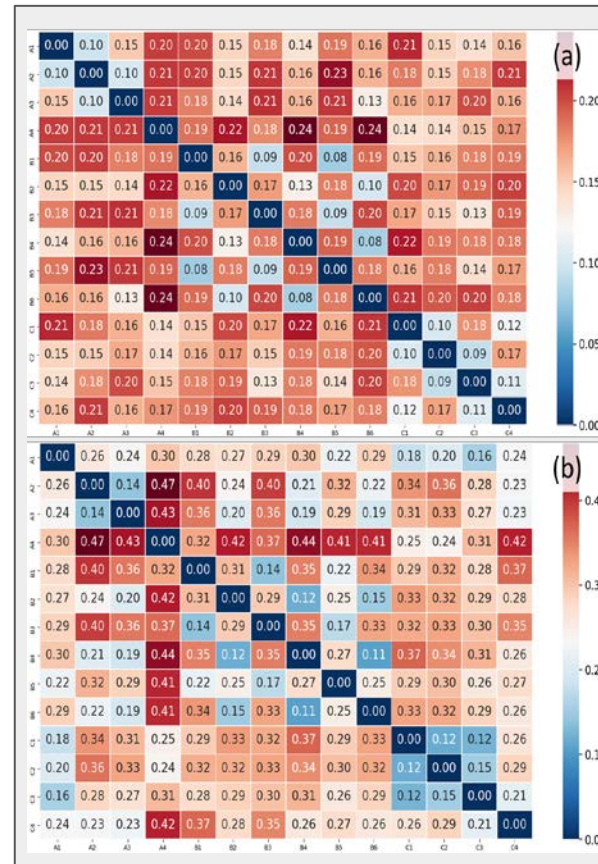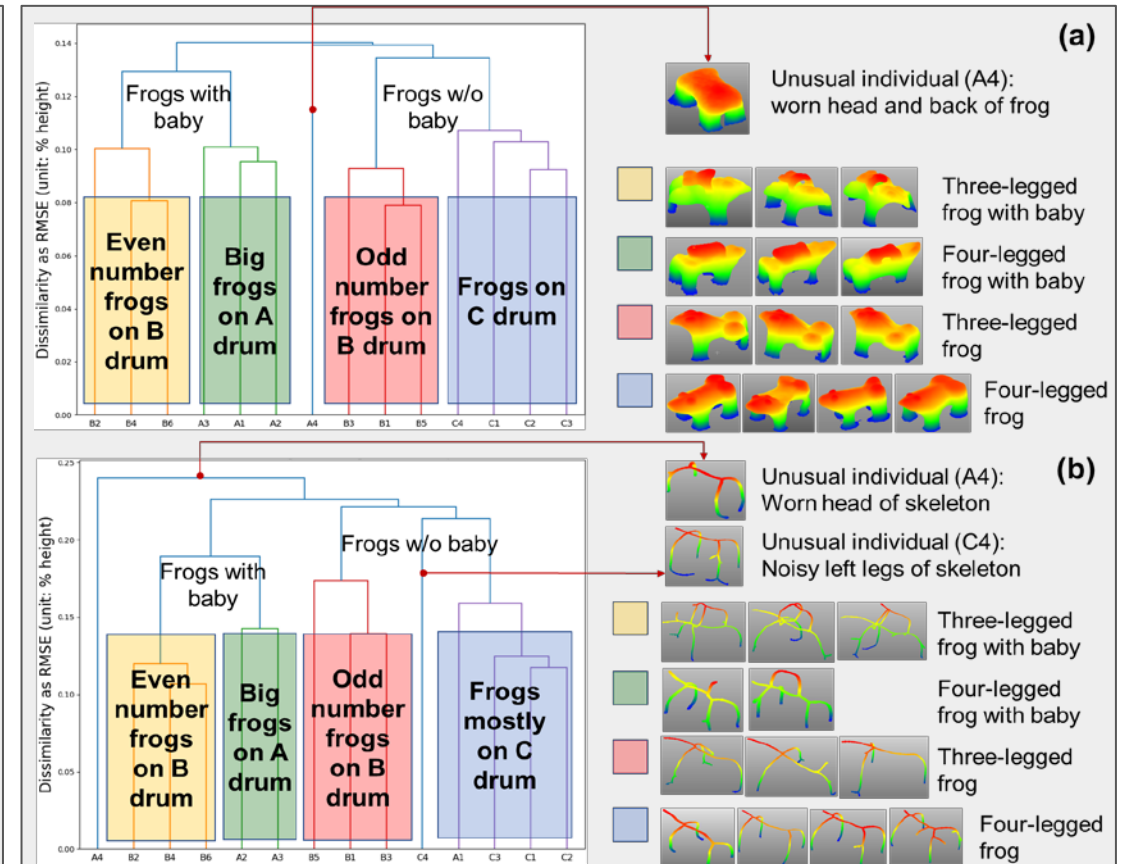- Comparison of results from the two sources
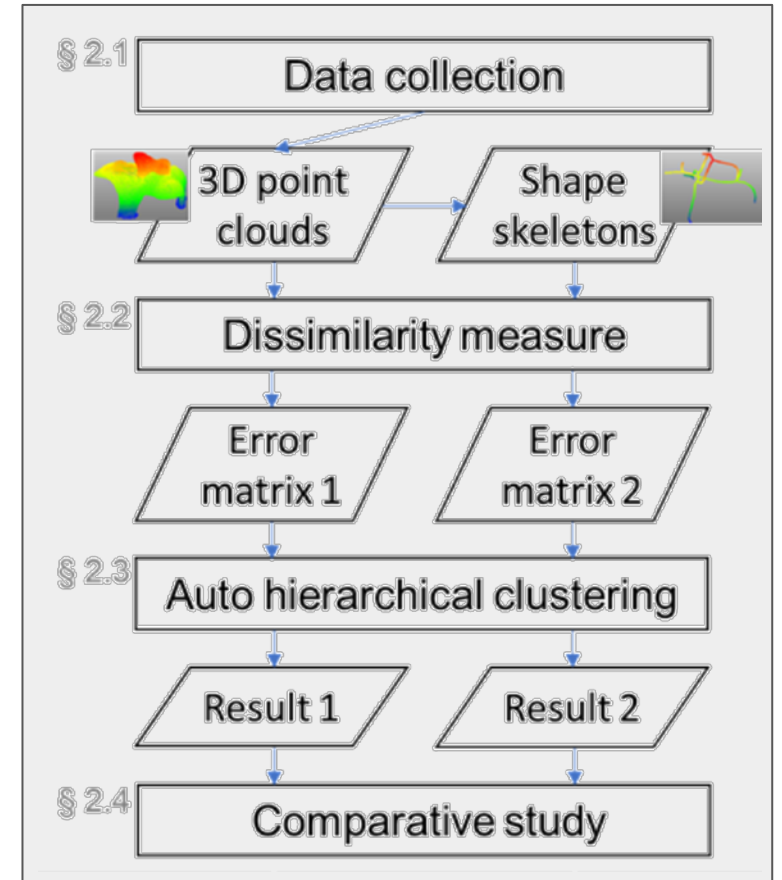
RESULTS

Dissimilarity matrices

- 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
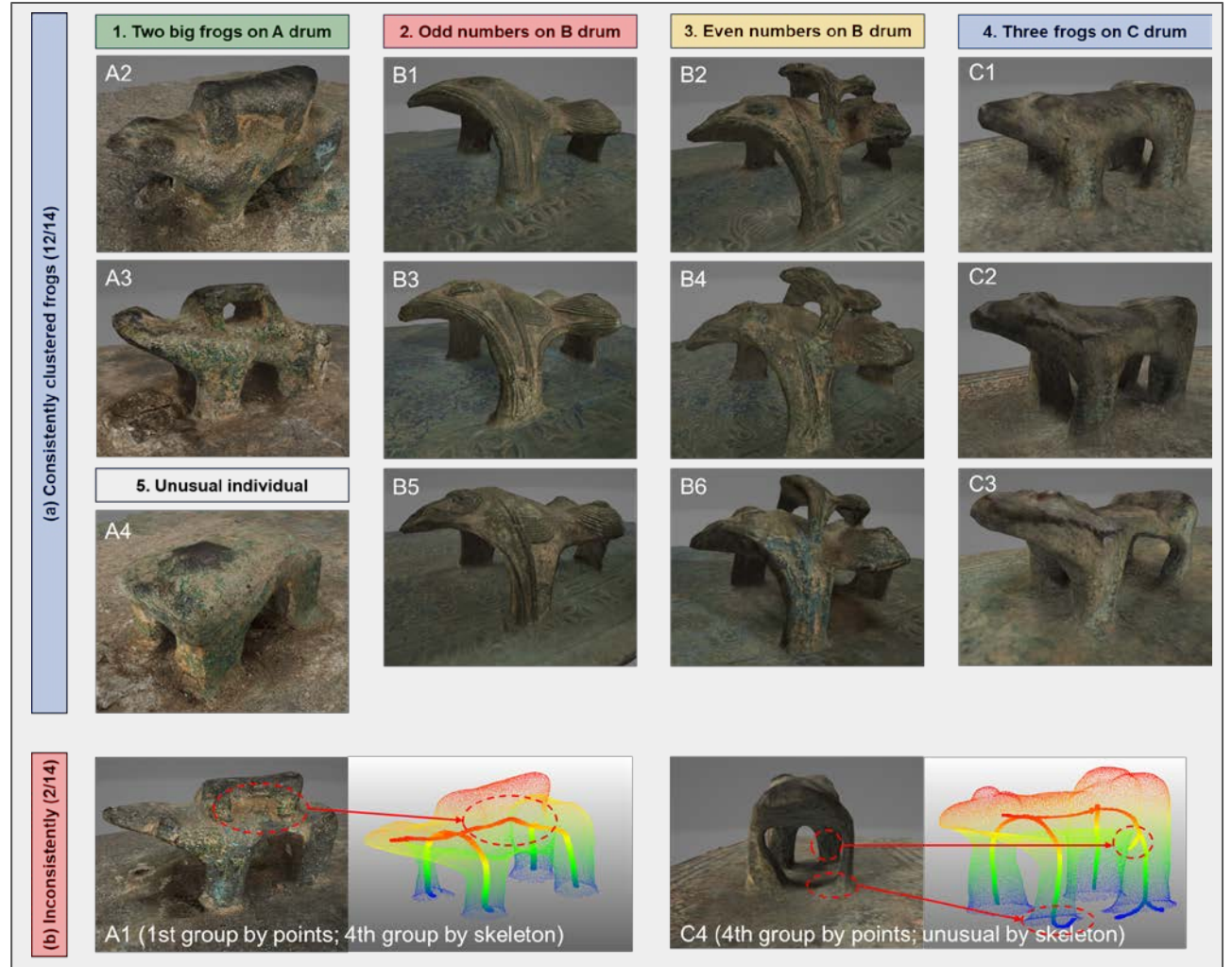

Dissimilarities
(a) Surface; (b) skeleton

Hierarchical clustering (threshold = (min+max)/2)

RESULTS

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 surface point clouds		Group using shape skeleton				
		I	II	III	IV	V
	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

(a) Consistently clustered frogs (12/14)

1. Two big frogs on A drum — A2, A3, A4
2. Odd numbers on B drum — B1, B3, B5
3. Even numbers on B drum — B2, B4, B6
4. Three frogs on C drum — C1, C2, C3
5. Unusual individual

(b) Inconsistently (2/14)

A1 (1st group by points; 4th group by skeleton)

C4 (4th group by points; unusual by skeleton)

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CONCLUSION

Bronze frogs on drums

- Widely spread in Ancient South China and Southeast Asia
- Qualitatively grouped and compared (similar to building Covid virus family tree)
- Both 3D surface and shape skeleton worked well
- An automatic way of grouping new 3D scans (not limited to frogs) from site

Future work
- Scale-up tests
- Examining the new values of skeletons (abstraction, topology, file size)
- Revised shape skeleton definitions for heritage data (e.g., tolerance to worn corners)
- Heritage Digital Twins with unsupervised learning

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