

Image-based Airborne LiDAR Point Cloud Encoding for 3-D Building Model Retrieval

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ISPRS 23rd

July 13th 2016

3-D City Models



How to obtain 3-D Building Models

1. Created manually
2. Generated by LiDAR or photogrammetry
- 3. Reuse data from Internet**



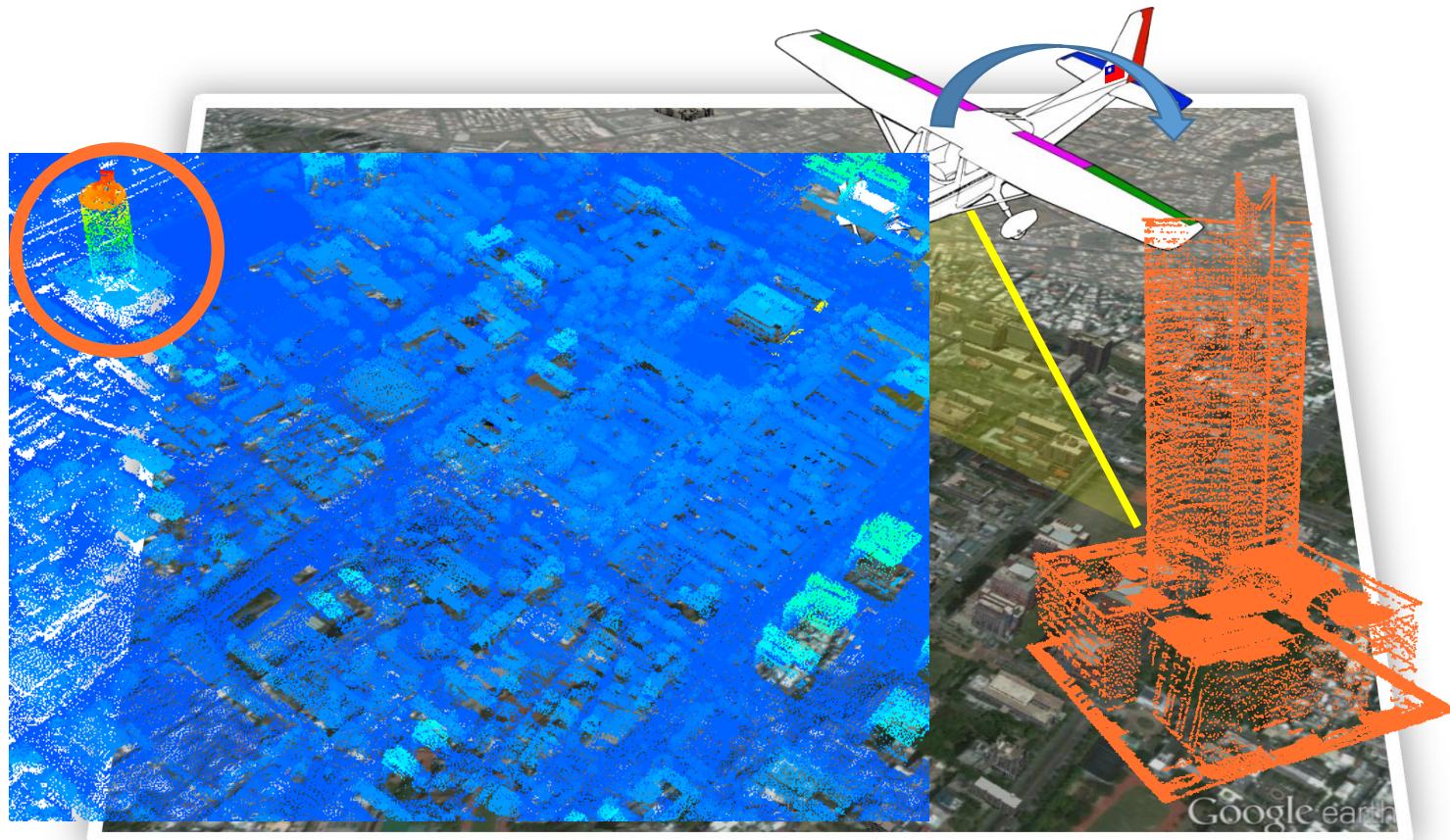
Basic Idea

- Data/Model reuse
 - Taipei 101 model



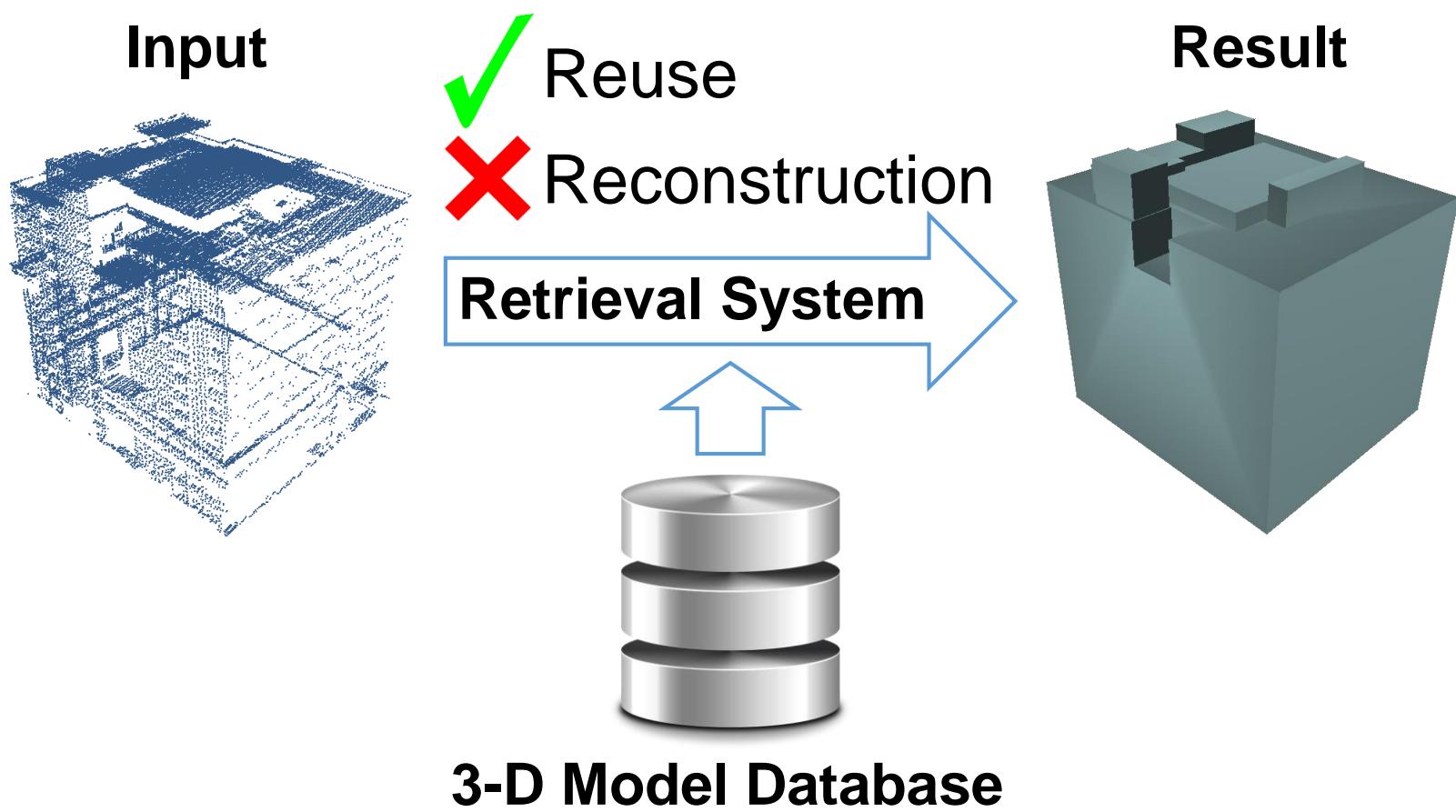
Airborne LiDAR

- An efficient tool to acquire 3-D spatial data



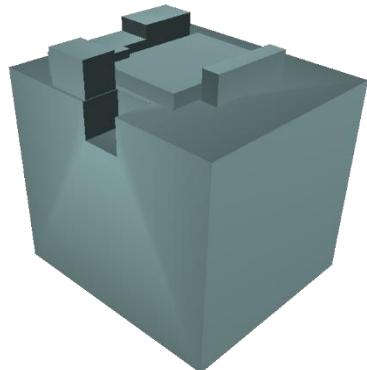
3-D Model Retrieval System

- For Automatic city modeling

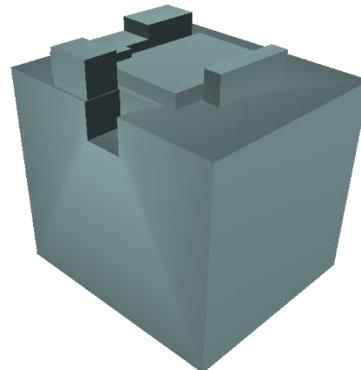


What's the challenge?

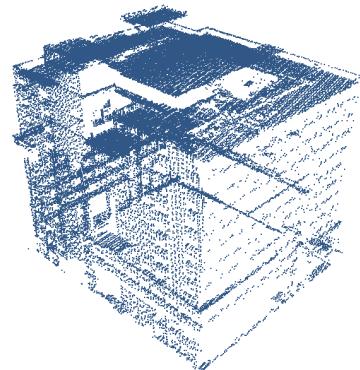
Input



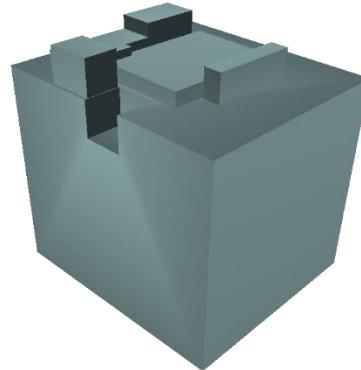
Result



Past

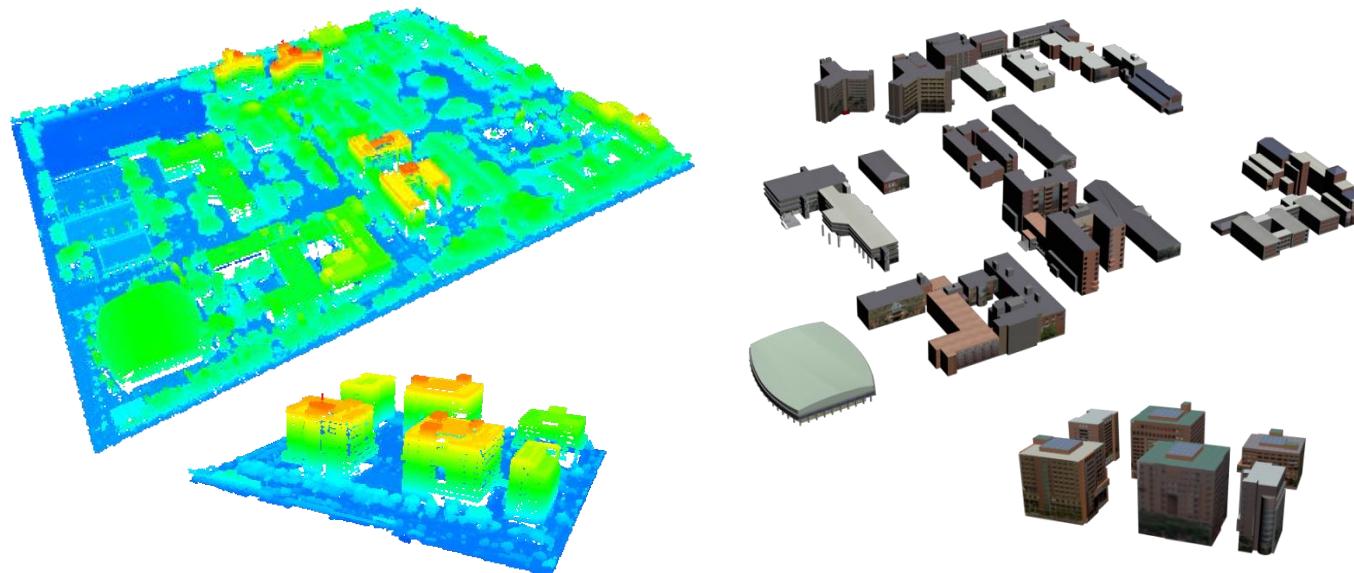


Now



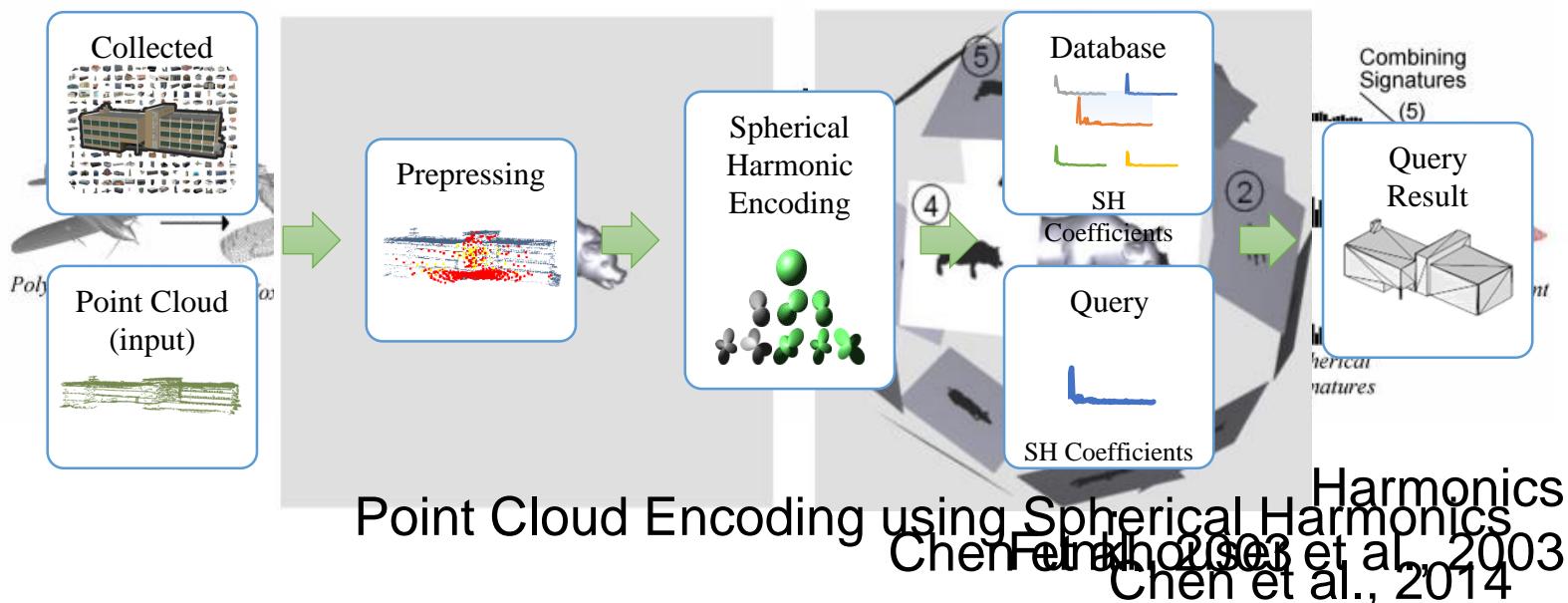
Objective

- Develop an encoding approach for
 - Point cloud
 - 3-D model
- Similarity = Comparison of encoding results

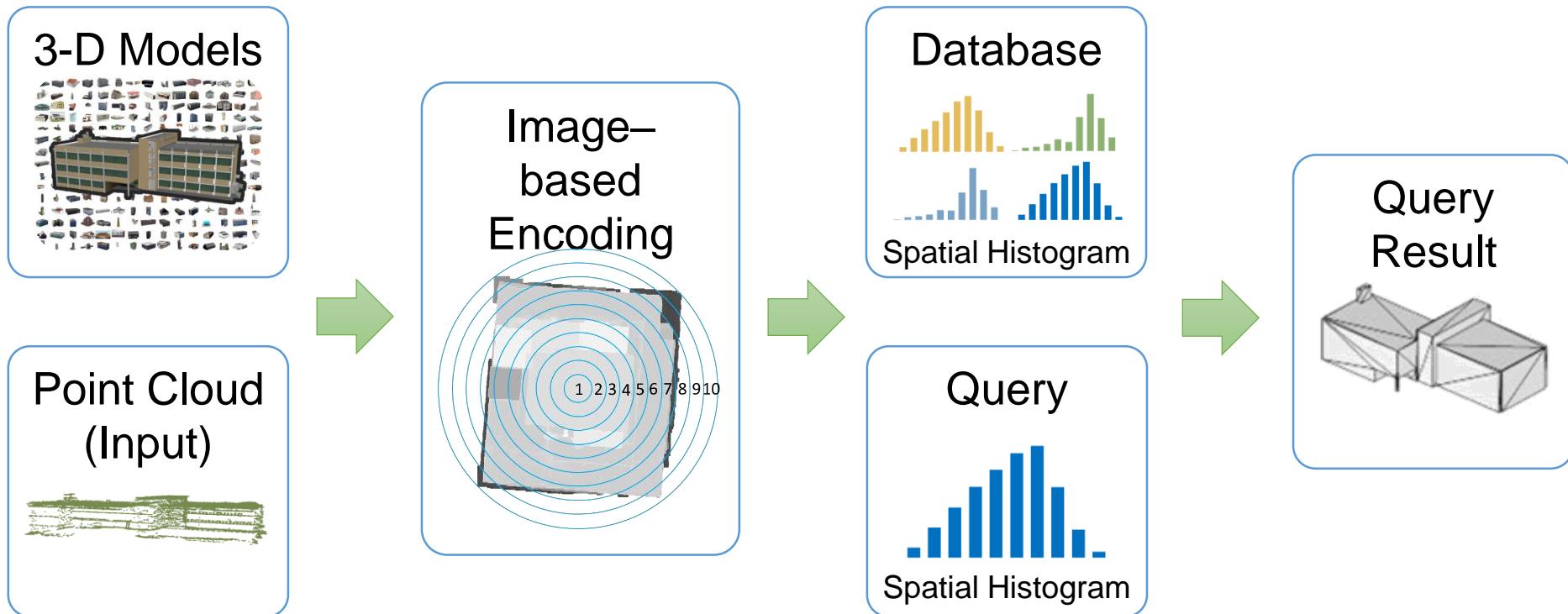


Related work

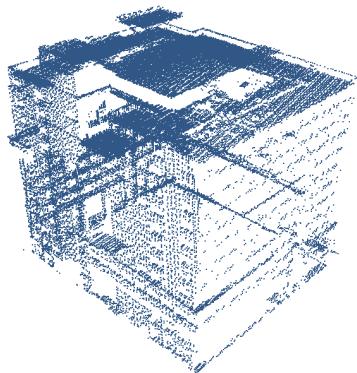
- Existing studies of model retrieval
 - Model-based
 - View-based
 - Point cloud as input



System Workflow



Why to encode



Similarity

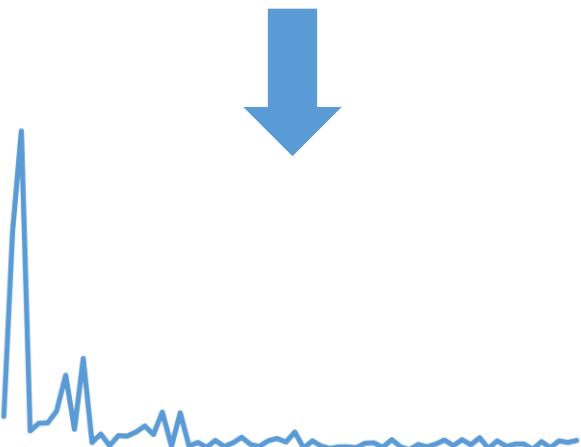
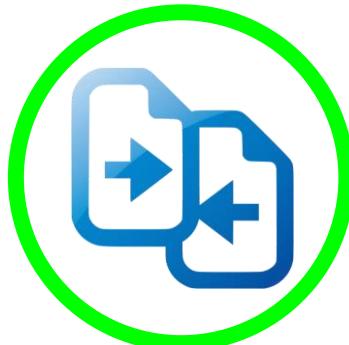
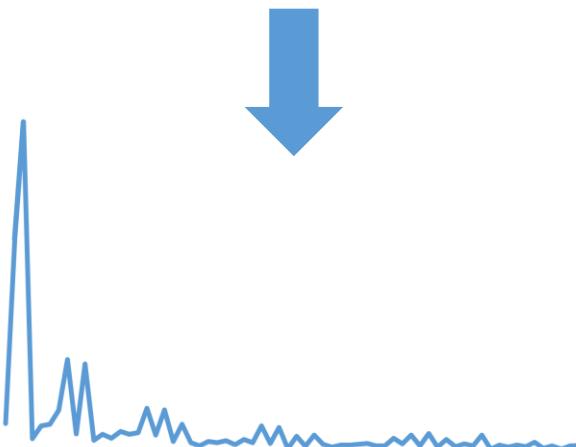
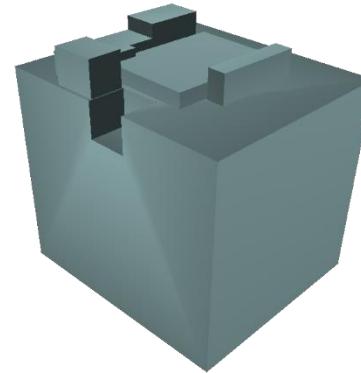
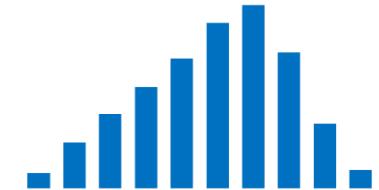
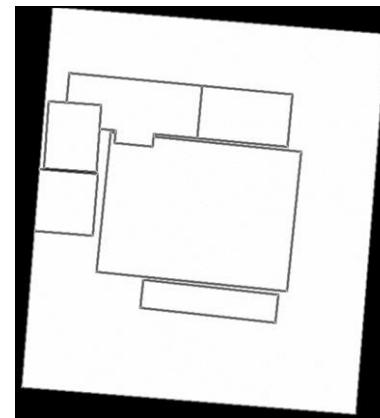
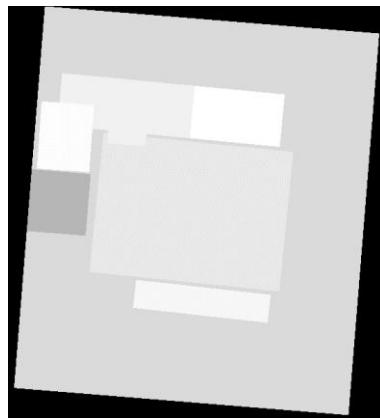
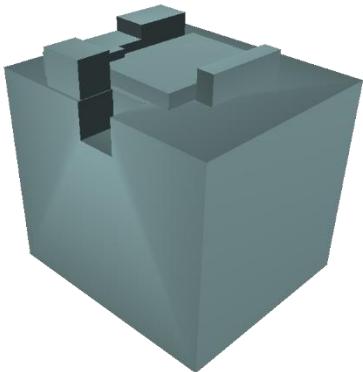


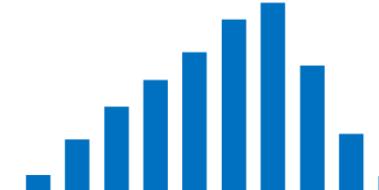
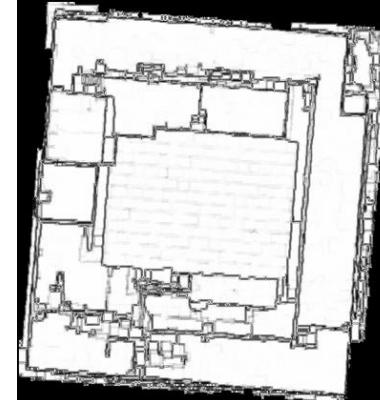
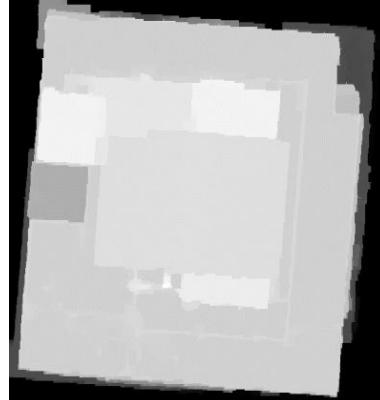
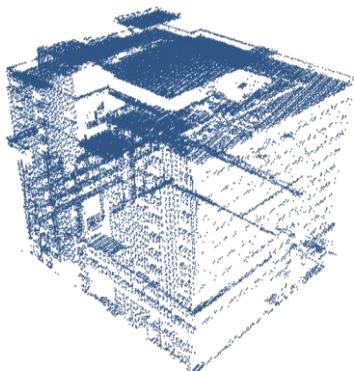
Image-based Encoding



Building
Roof
Description

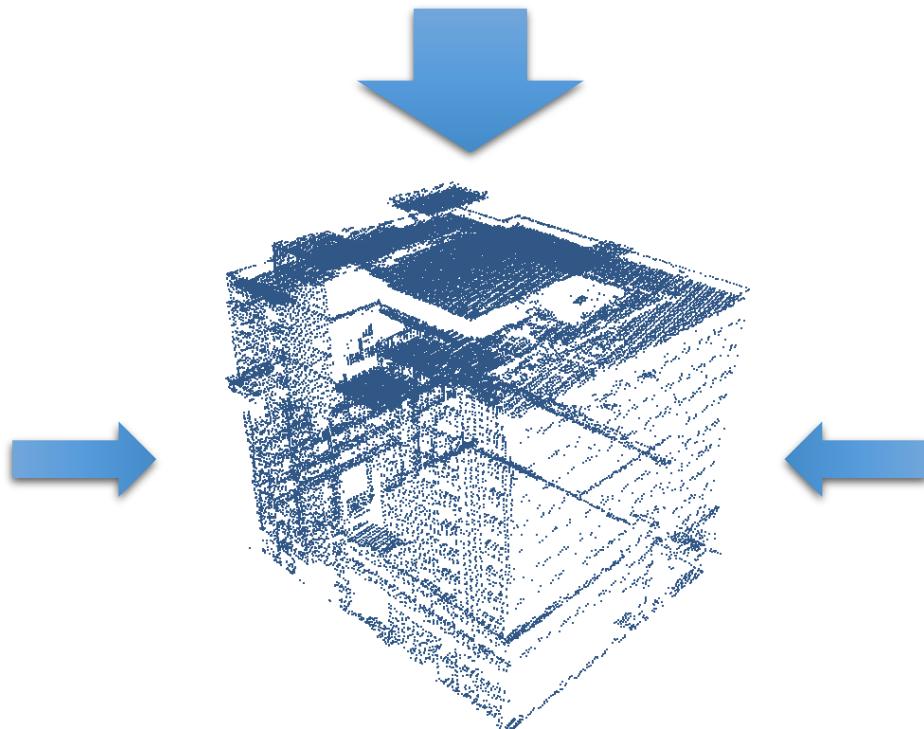
Geometric
Features

Spat
Histog

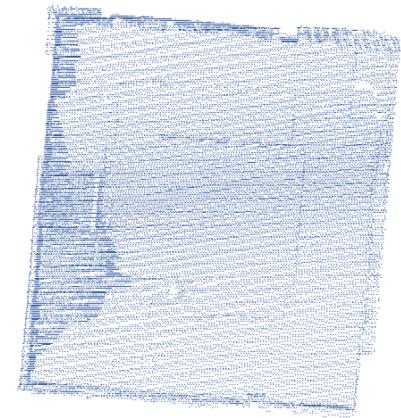


Encoding – Depth Image

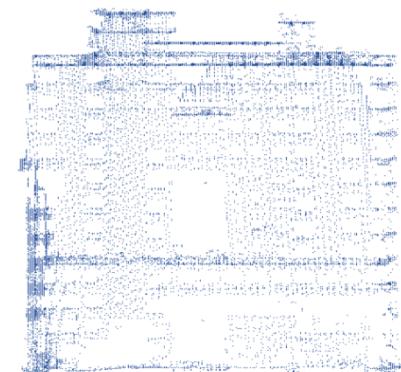
- Motivation
 - Less information in side parts
 - **More information in roof parts**



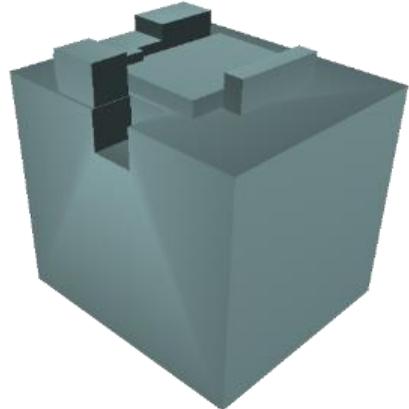
Top View



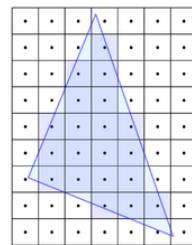
Side View



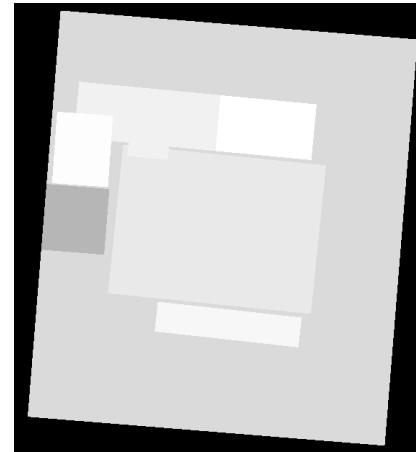
Encoding – Depth Image



Building Object



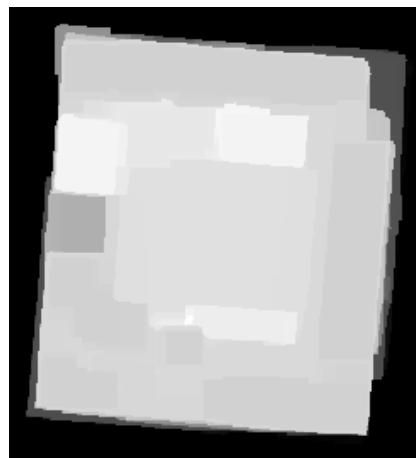
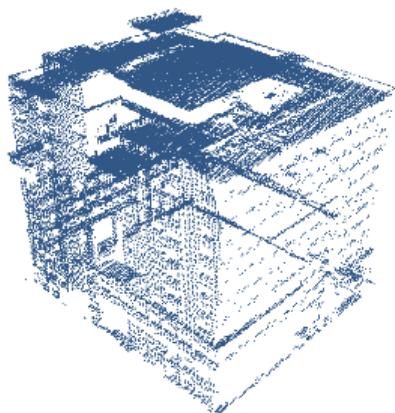
Rasterization



Max. Height



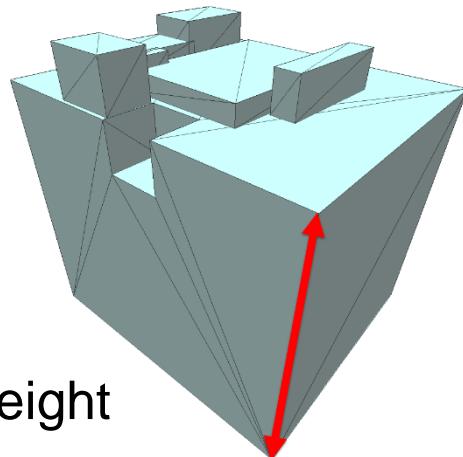
Depth Image



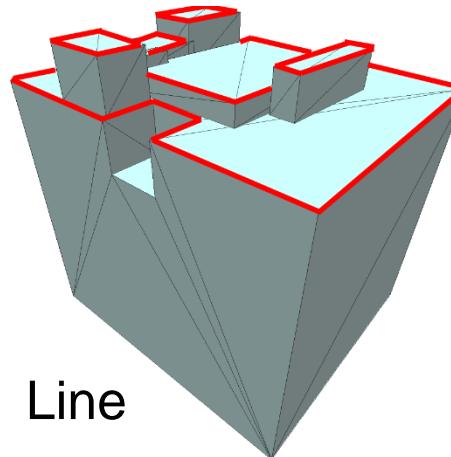
Ground

Encoding – Geometric Features

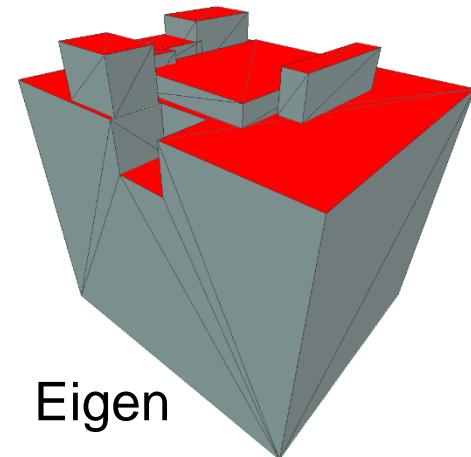
- Height feature
 - Height from the ground
- Line feature
 - Laplacian of Gaussian edge detection
- Eigen feature
 - Planarity



Height

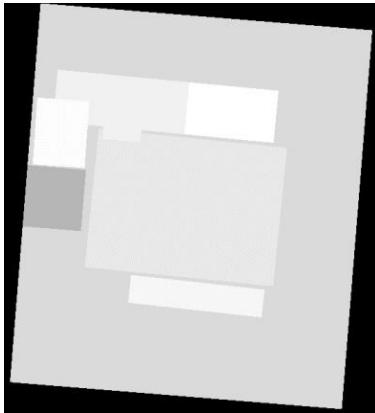
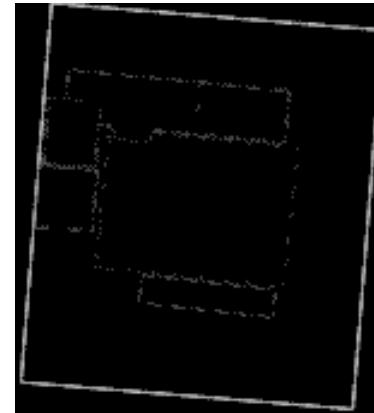
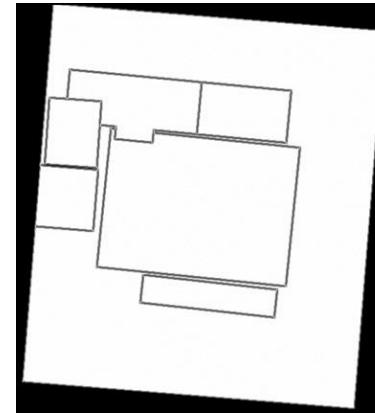
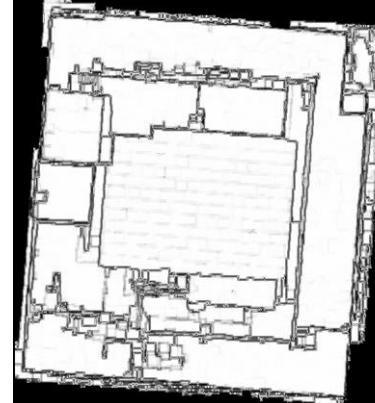


Line

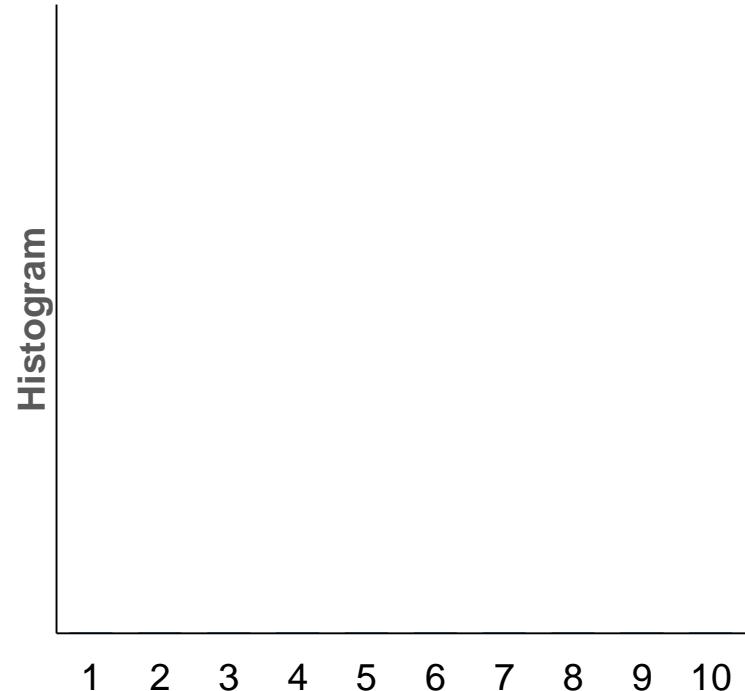
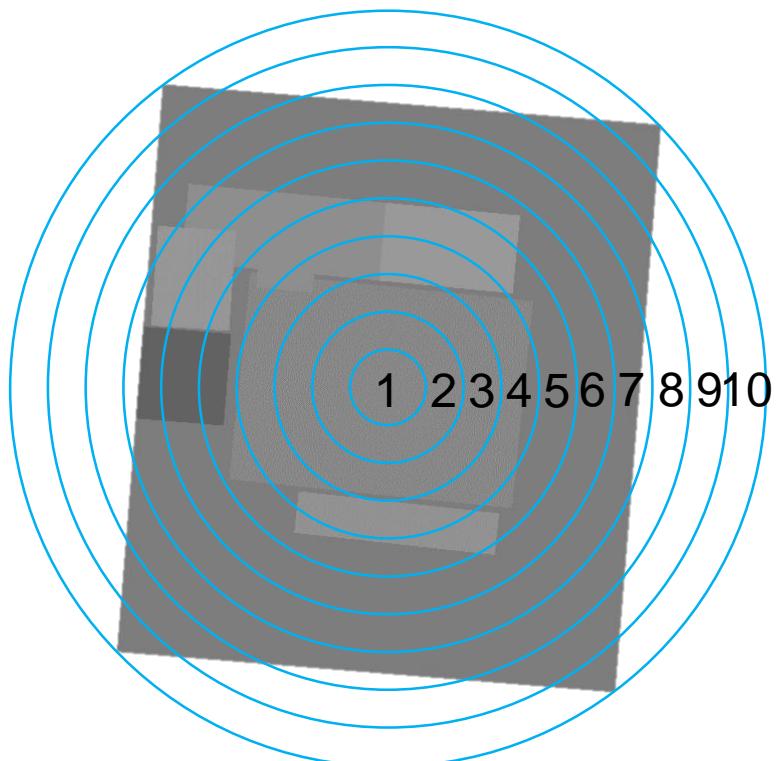


Eigen

Encoding – Geometric Features

	Height	Line	Eigen
3-D Model			
Point Cloud			

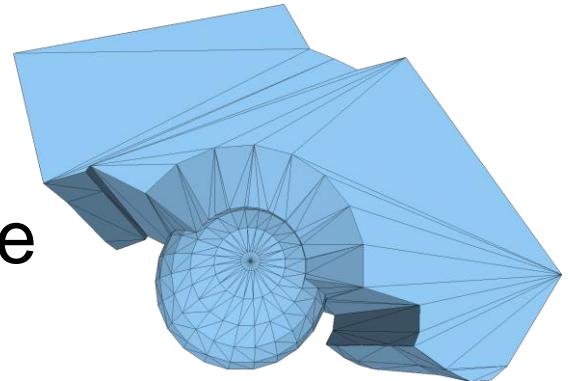
Encoding – Spatial Histogram



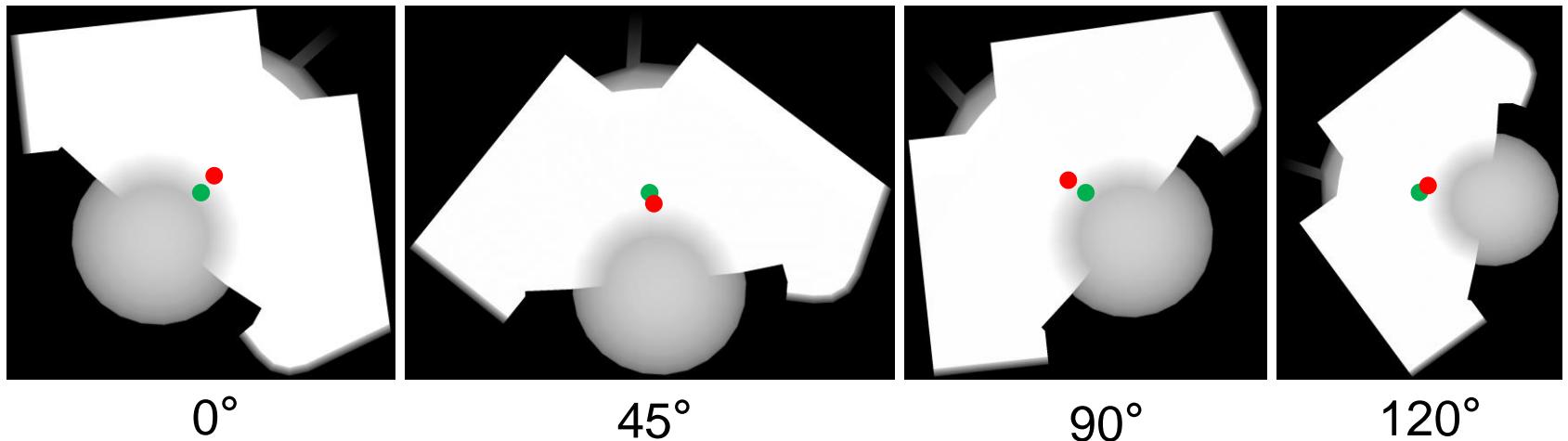
Origin Determination

- Center of mass in 3-D
- Rotation and translation Invariance

- Center of Mass in 3-D
- Center of Minimal Bounding Box



Living Mall (Taipei)



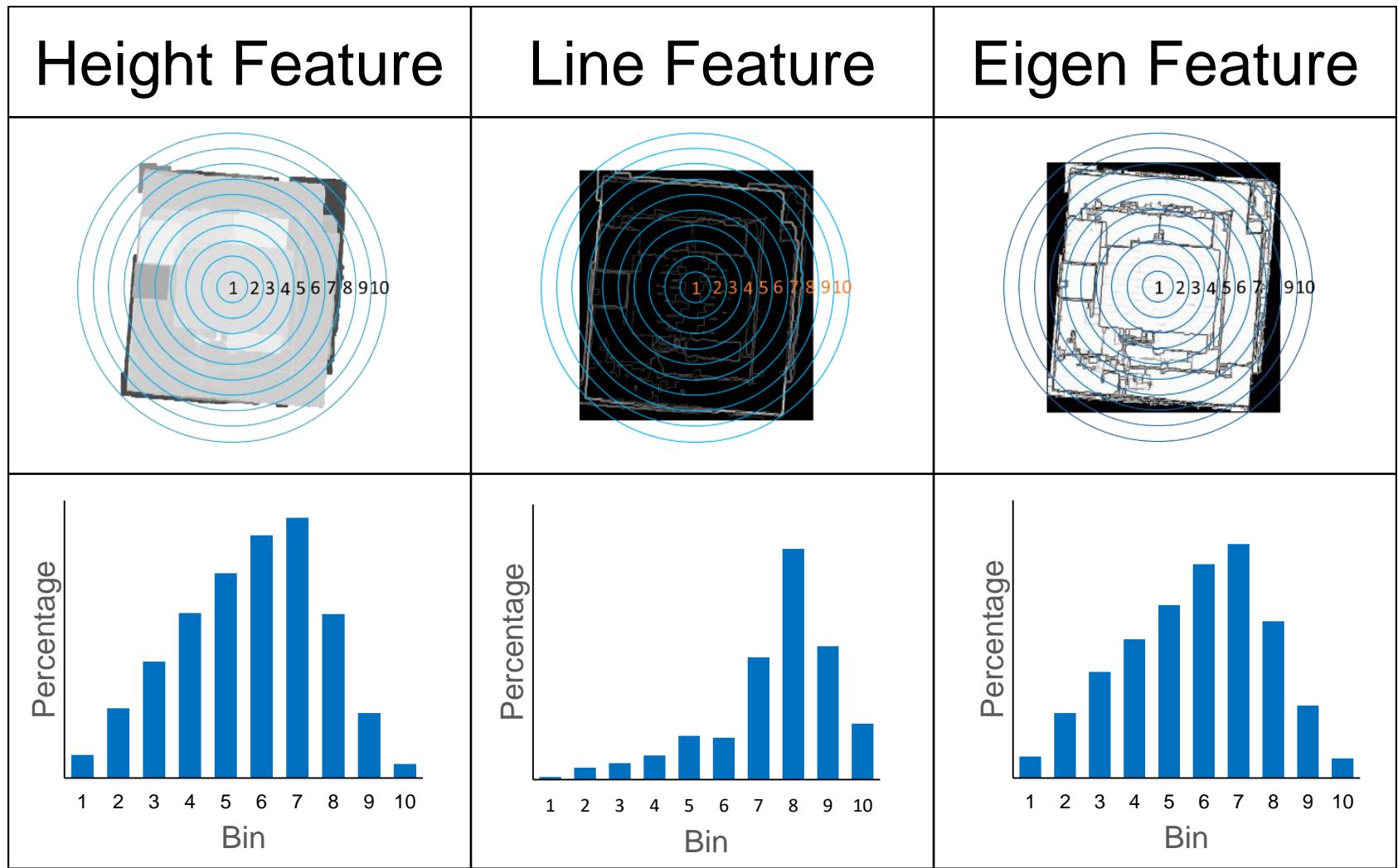
0°

45°

90°

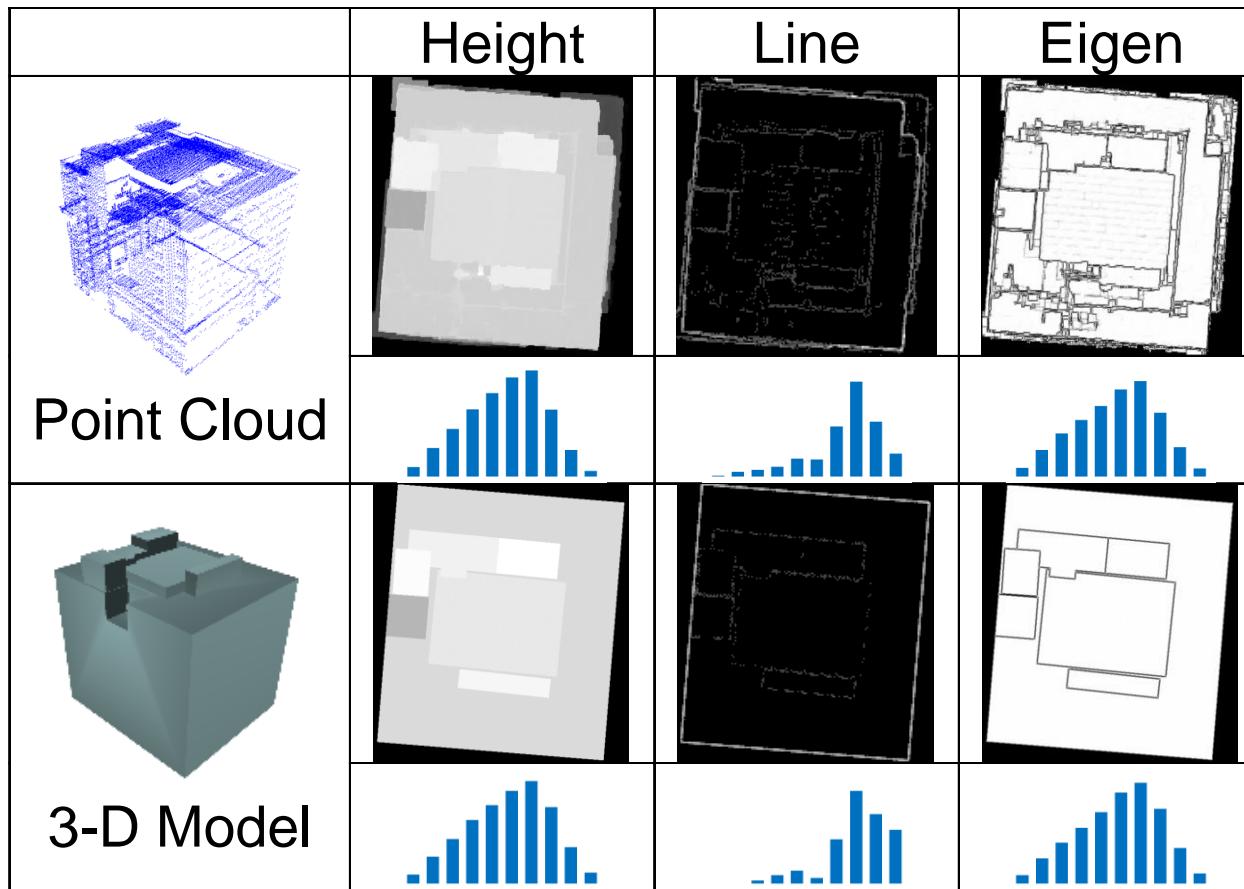
120°

Encoding – Spatial Histogram



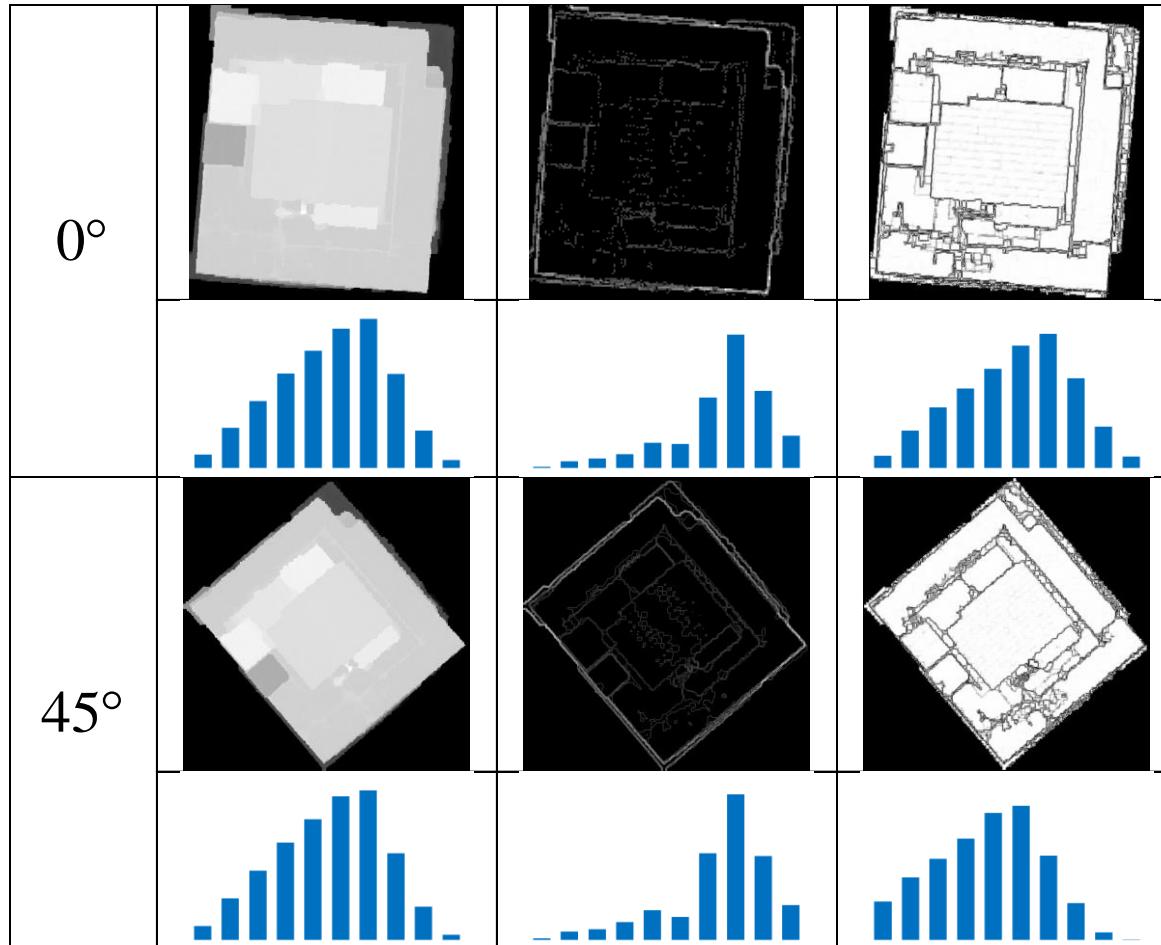
Encoding Property 1

- Consistent encoding of point clouds and building models



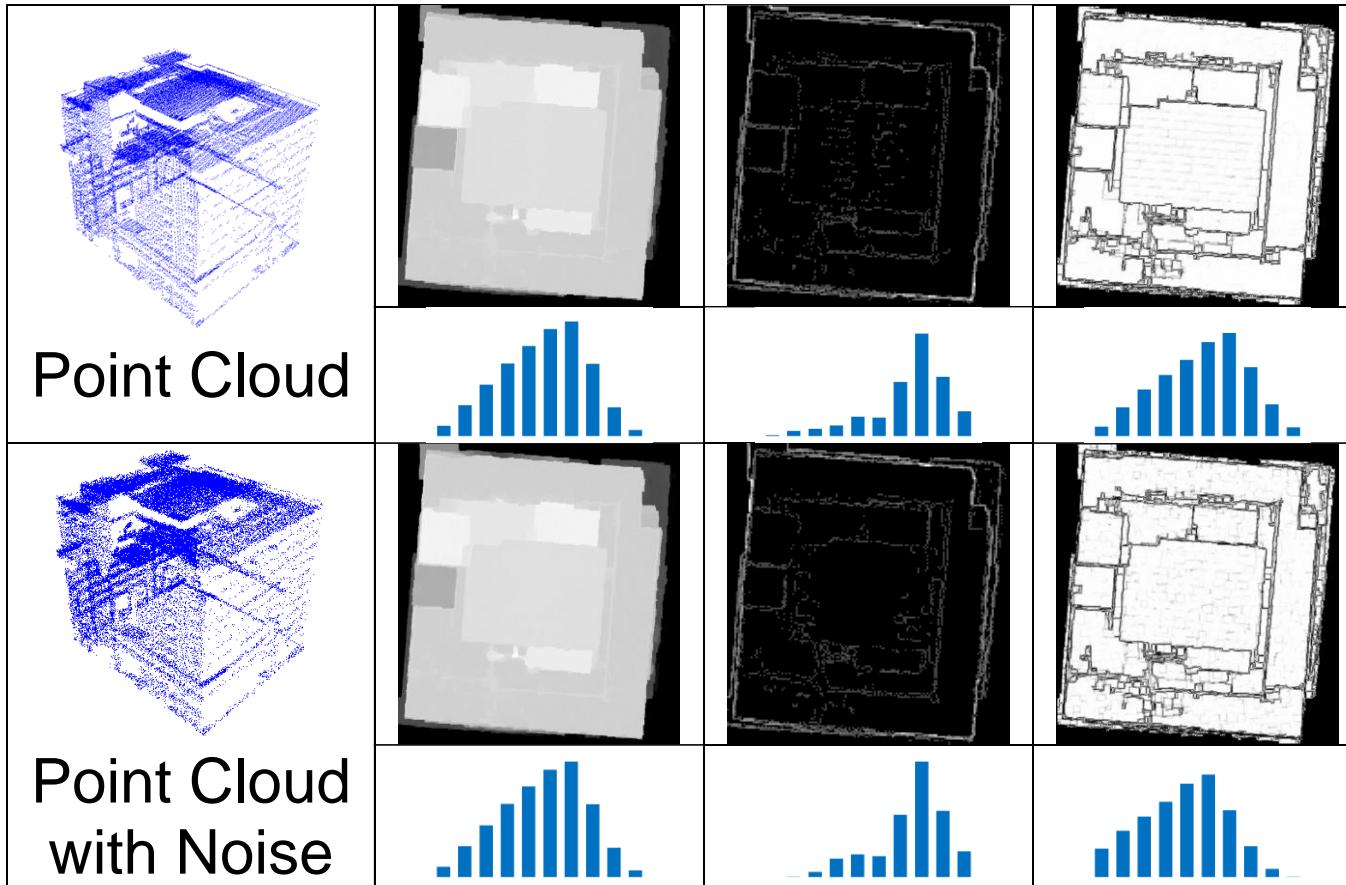
Encoding Property 2

- Demonstration of rotation invariance



Encoding Property 3

- Demonstration of noise insensitivity



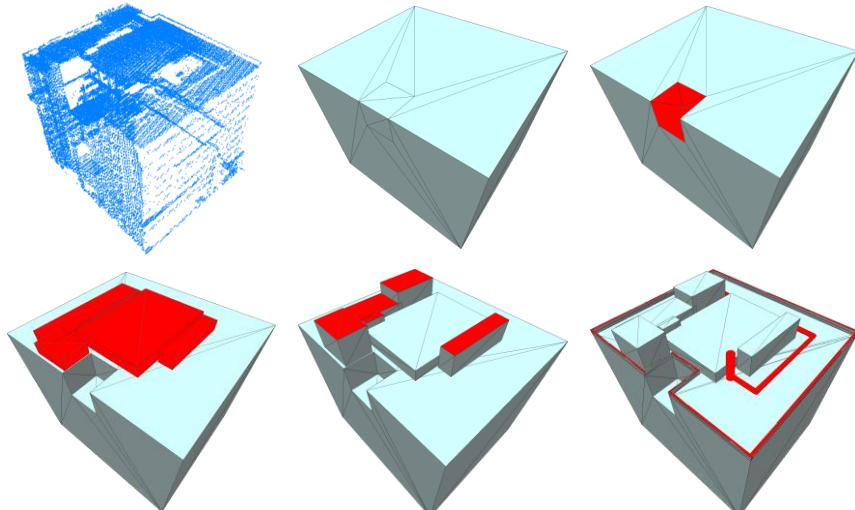
Database



1 Million Models

Evaluation

1. Encoding of various level-of-detail (LoD) models
2. Data retrieval from a database

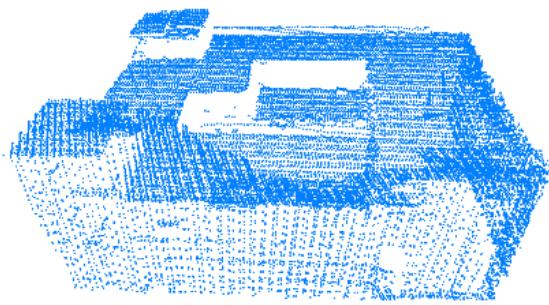


1. LoD

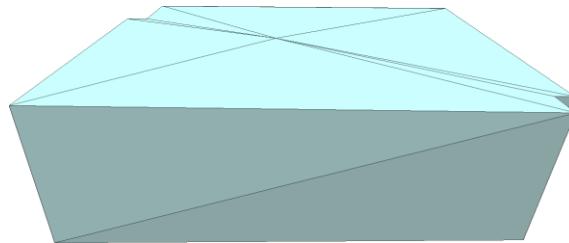


2. Database

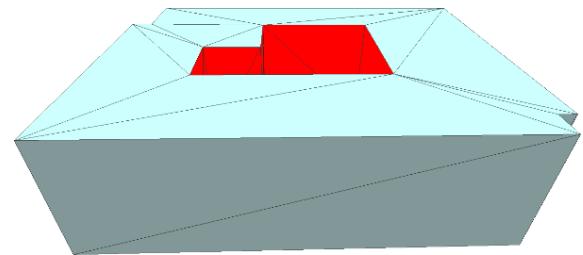
LoD – Experimental Result 1



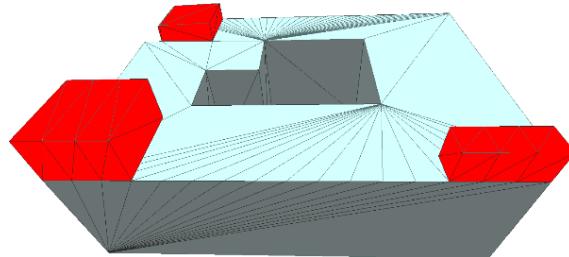
Point Cloud



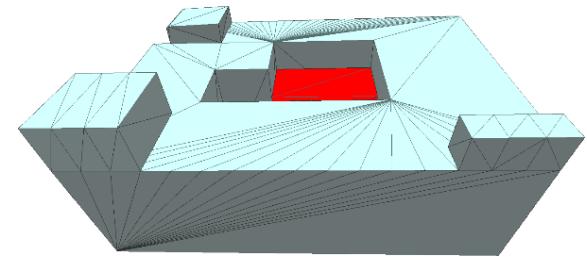
Detail-1: 1.024



Detail-2: 0.905

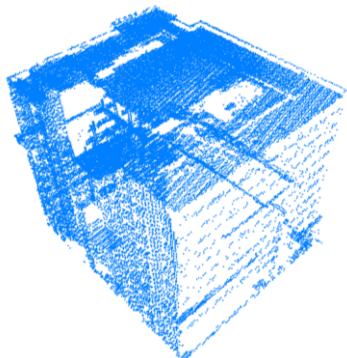


Detail-3: 0.718

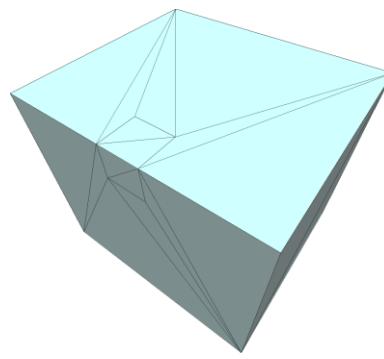


Detail-4: 0.349

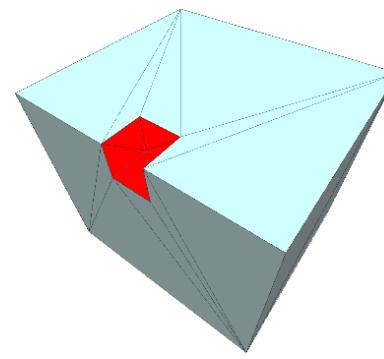
LoD – Experimental Result 2



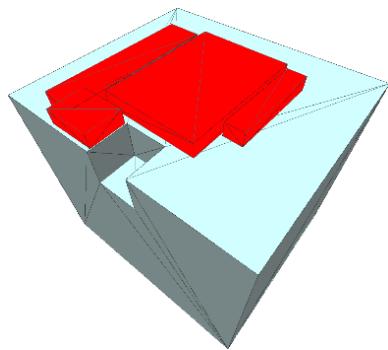
Point Cloud



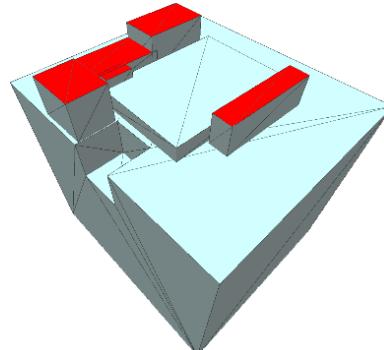
Detail-1: 1.150



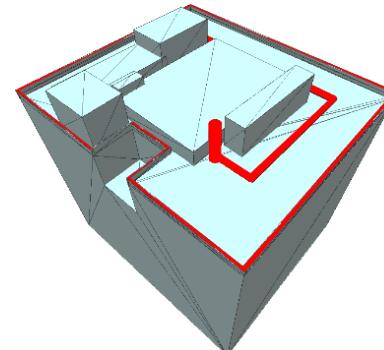
Detail-2: 0.985



Detail-3: 0.552



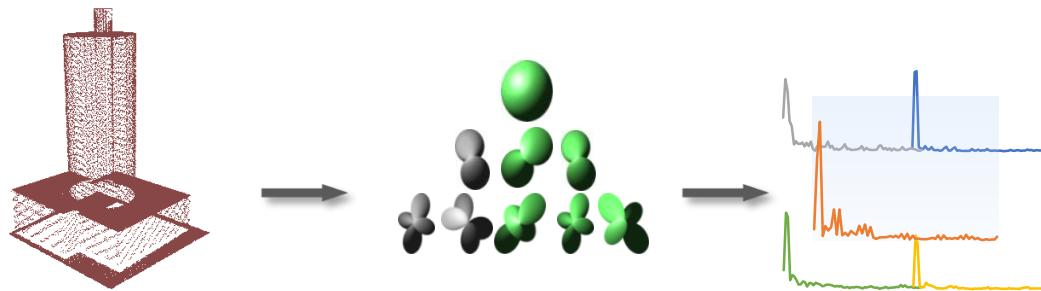
Detail-4: 0.267



Detail-5: 0.205

Comparison – Data Retrieval

- Point cloud encoding for 3-D building model retrieval
- Model-based
- Spherical harmonic function

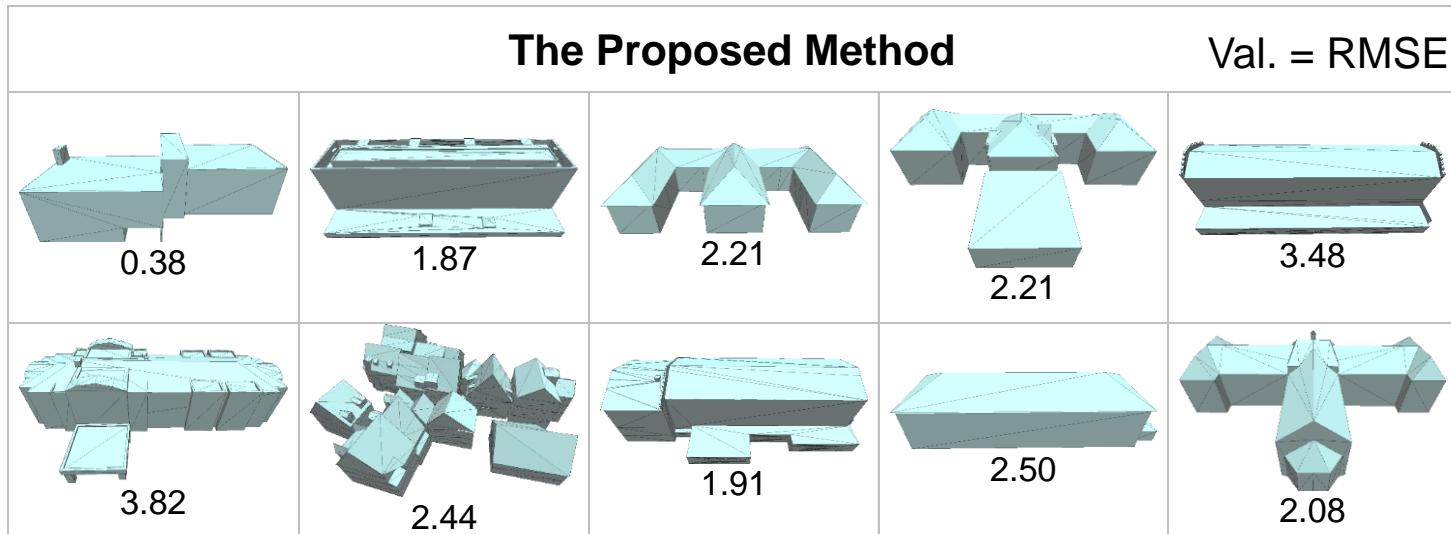
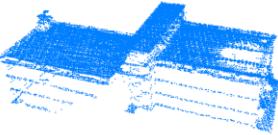


Reference:

Chen, J.-Y., Lin, C.-H., Hsu, P.-C., and Chen, C.-H., 2014. Point cloud encoding for 3-D building model retrieval. *IEEE Trans. on Multimedia*, 16(2), pp. 337–345.

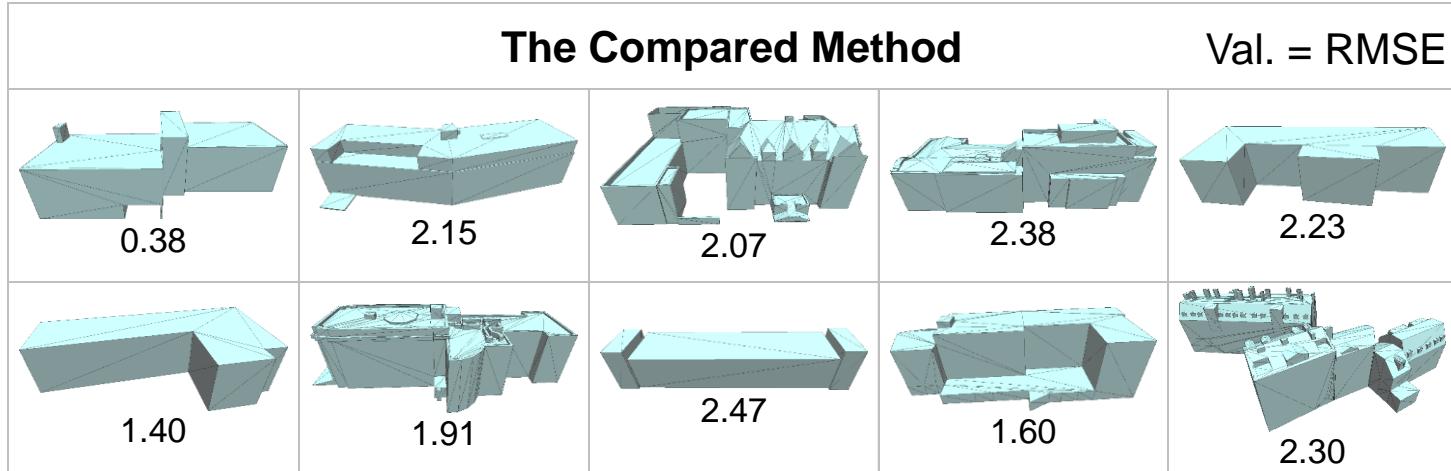
Database – Experimental Result 1

Building #1



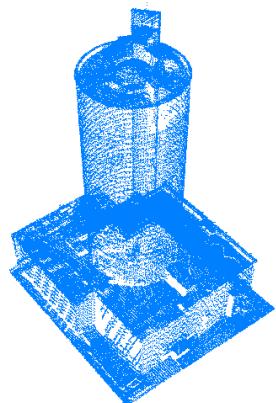
The Compared Method

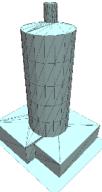
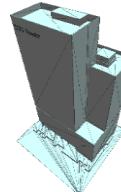
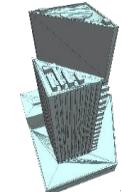
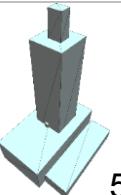
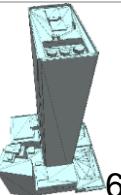
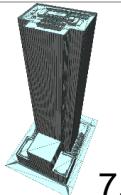
Val. = RMSE

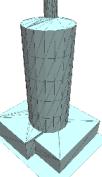
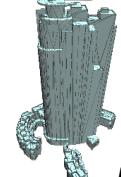
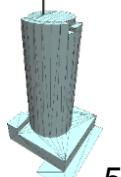
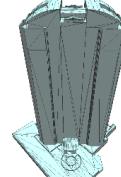
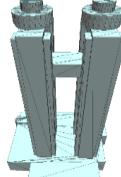
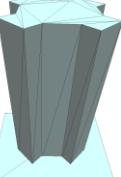
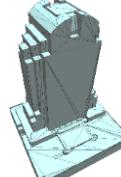
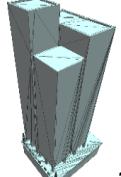


Database – Experimental Result 2

Building #2

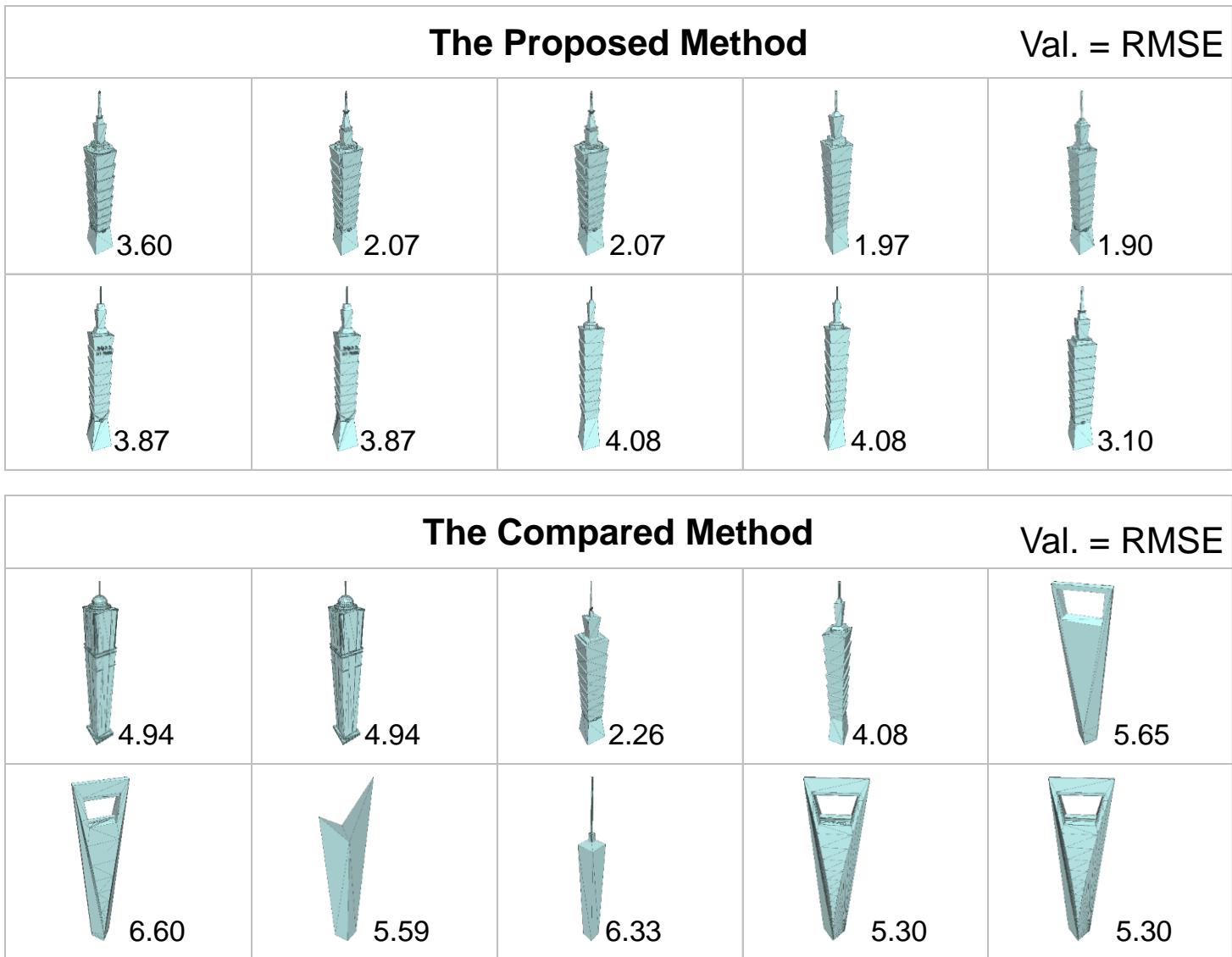


The Proposed Method					Val. = RMSE
					2.16 7.17 8.40 5.82 7.60
					5.96 5.96 5.96 6.04 7.17

The Compared Method					Val. = RMSE
					2.16 5.84 5.21 8.88 8.52
					7.64 7.00 9.34 5.14 10.42

Database – Experimental Result 3

Building #3



Database – Experimental Summary

The Proposed Method			
	Building 1	Building 2	Building 3
RMSE Avg.	1.89	6.22	3.06
Rank Diff. Sum	50	32	24

The Compared Method			
	Building 1	Building 2	Building 3
RMSE Avg.	2.29	7.01	5.10
Rank Diff. Sum	63	64	83

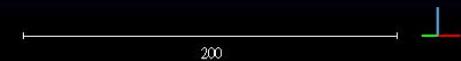
$$\text{Rank Diff. Sum} = \sum \left(\text{Abs}(\text{Encoding Rank} - \text{RMSE Rank}) \right)$$



Demo (Web-based Application)

ccViewer V1.34
Options Shaders Help

— □ ×



Conclusions and Future Work

- 3-D Building models in the database and the input point cloud can be consistently and accurately encoded.
- Spatial histogram introduces the properties of rotation invariance and noise insensitivity.
- A web-based model retrieval system has been developed.
- Description of geometric shape and building size are added for whole building.



The End

