GigaVision Challenge

When Gigapixel Videography Meets Computer Vision

Track：Reconstruction

Team name：DTM3D

Team Introduction

Zizhuang Wei is currently an **AI algorithm researcher** in **Digital Twin Lab, Huawei**. He received the Ph.D degree from Graphics and Interaction Lab, Dept. of EECS, Peking University. His research interests focus on 3D reconstruction and deep learning.

Qingtian Zhu is currently a **master student** at Graphics and Interaction Lab (GIL) of **Peking University**. His research interests include 3D reconstruction and computational photogrammetry.

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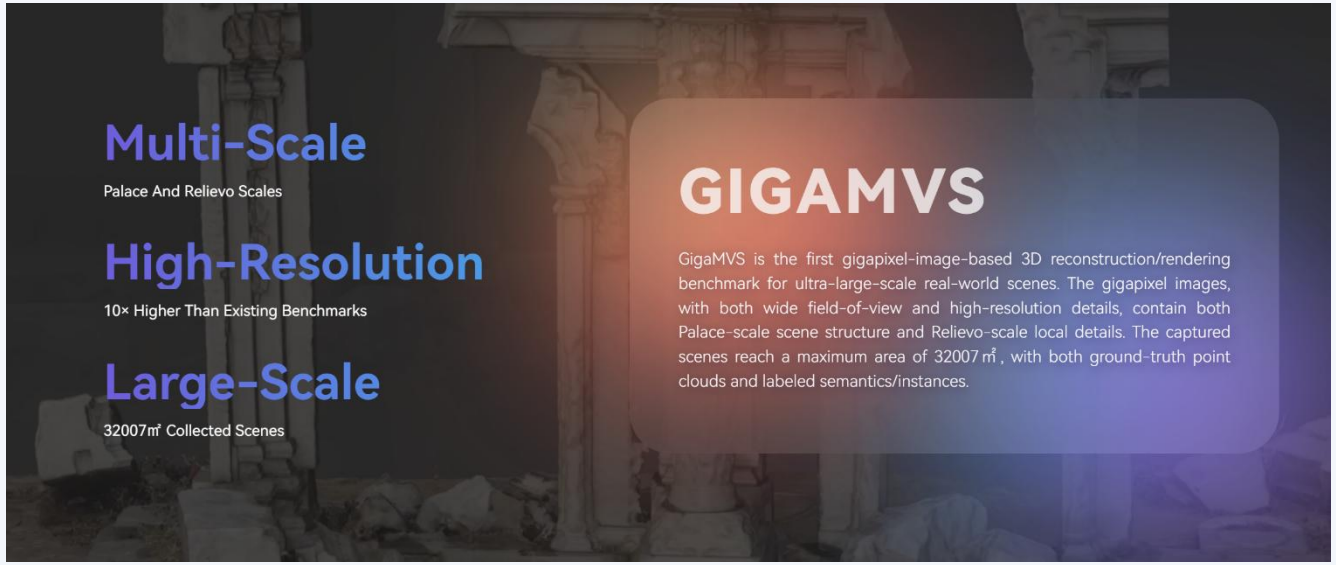
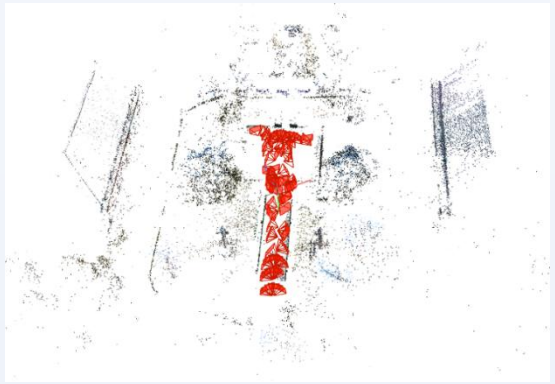
Task Analysis



Original Images



Camera poses

Challenges

- Very high resolution
- Weakly textured walls and floors
- Sparse view reconstruction
- Severe occlusion
- Unbounded scenario
- Large area of sky
- Complex lighting conditions
- ……

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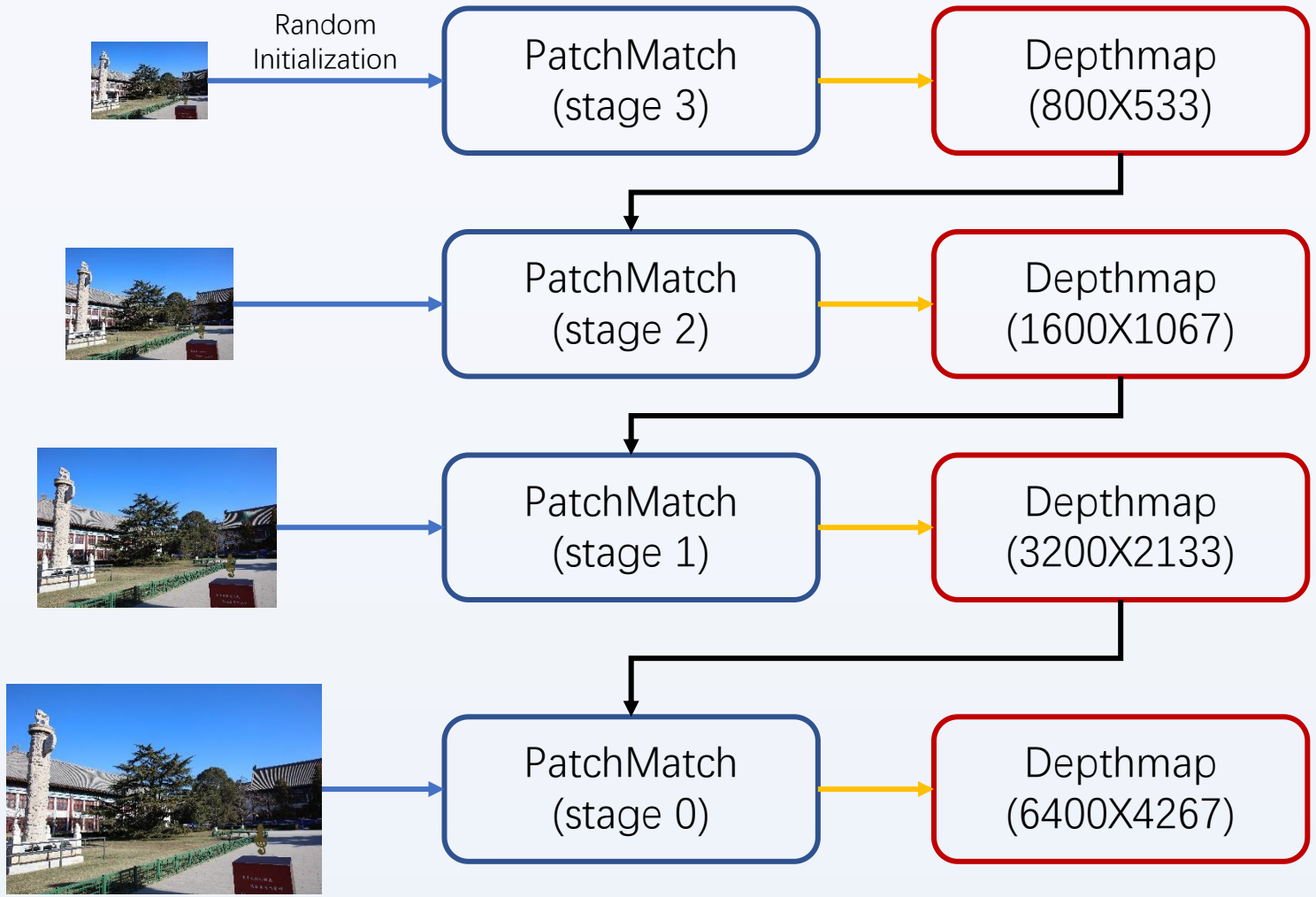
Solution and Innovation



Multiscale depth inference

Multi-scale depth estimation framework is used to enhance weak texture regions, and **PatchMatch** method is used for feature matching at each stage (Learning features are not used due to memory limitations).

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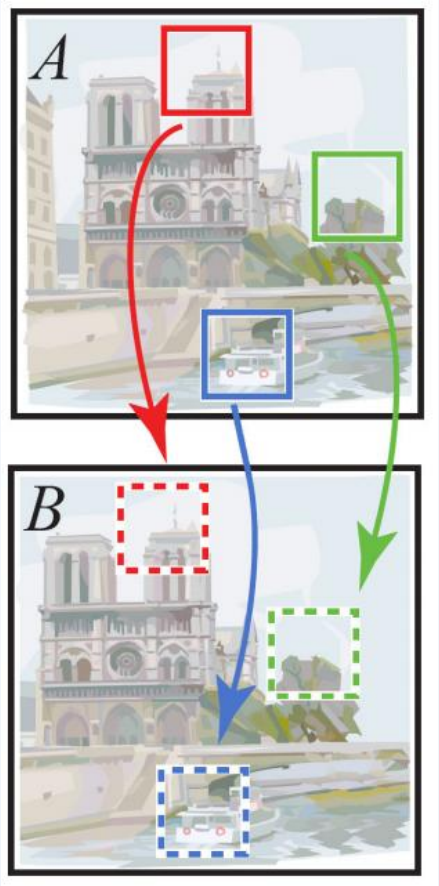
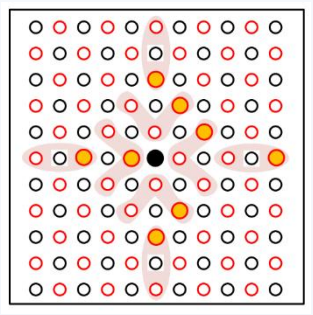
Solution and Innovation





$$\mathrm{M} = \begin{bmatrix} m_{1,1} & m_{1,2} & \cdots & m_{1,N-1} \\ m_{2,1} & m_{2,2} & \cdots & m_{2,N-1} \\ \vdots & \vdots & \ddots & \vdots \\ m_{8,1} & m_{8,2} & \cdots & m_{8,N-1} \end{bmatrix}$$

$$\rho_l^m = \frac{\mathrm{cov}_w(\boldsymbol{w}_l, \boldsymbol{w}_l^m)}{\sqrt{\mathrm{cov}_w(\boldsymbol{w}_l, \boldsymbol{w}_l)\ \mathrm{cov}_w(\boldsymbol{w}_l^m, \boldsymbol{w}_l^m)}}$$

Adaptive checkerboard sampling scheme[1] is used for parallel propagation on GPU.

Multi-Hypothesis joint view selection[1] is used to reduce the impact of bad views.

Bilaterally weighted NCC[2] is used to measure the multi-view similarity.

PatchMatch and propagation

[1] Qingshan Xu and Wenbing Tao. Multi-scale geometric consistency guided multi-view stereo. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, pages 5483–5492, 2019.

[2] Johannes L Schönberger, Enliang Zheng, Jan-Michael Frahm, and Marc Pollefeys. Pixelwise view selection for unstructured multi-view stereo. In European Conference on Computer Vision, pages 501–518. Springer, 2016

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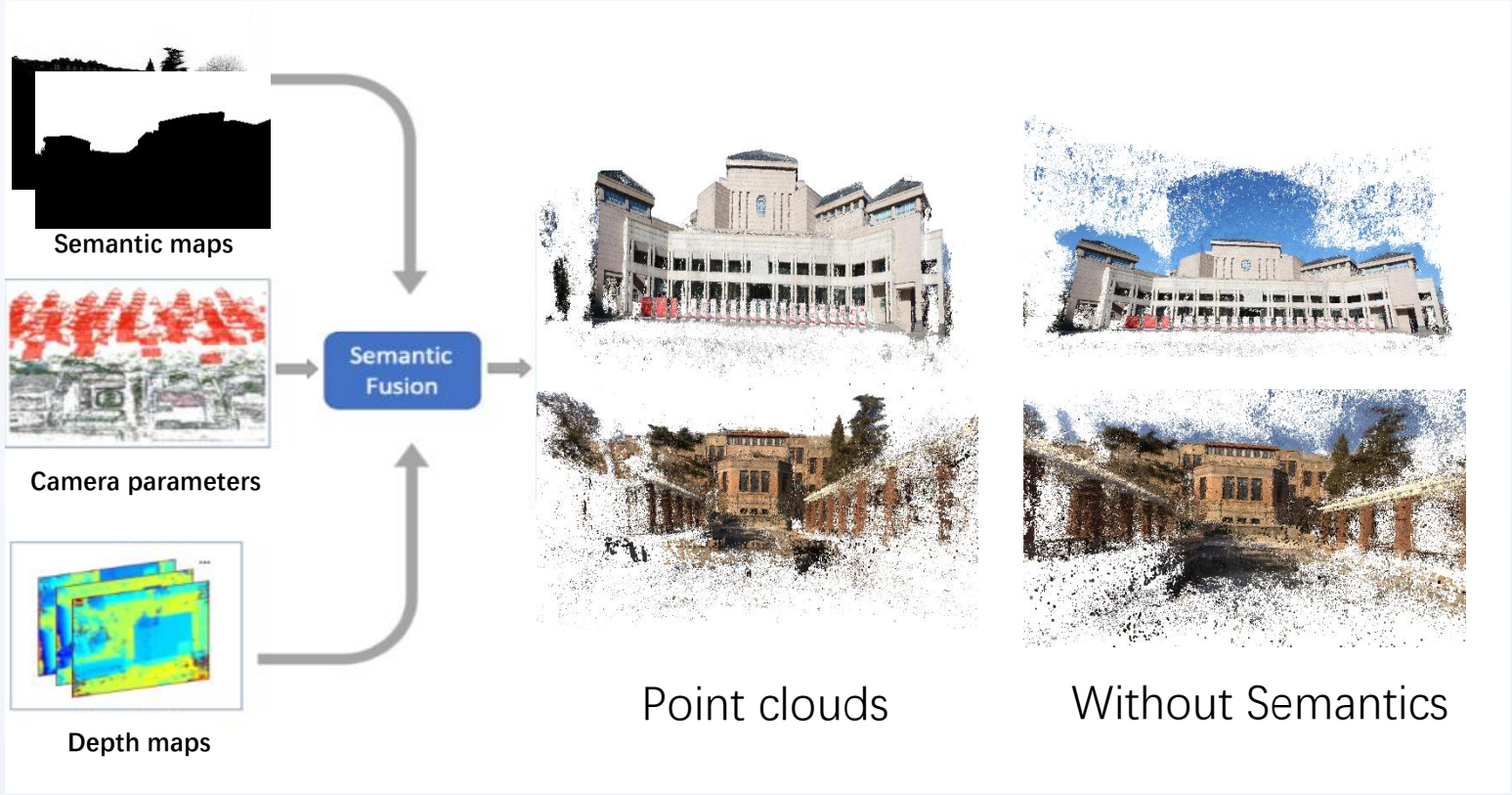
Solution and Innovation



Semantic & depth fusion

Dynamic depth map fusion algorithm[3] is used to filter the unreliable depths , while **Semantic maps** is used to remove the error points generated by sky area.

[3] Jianfeng Yan, Zizhuang Wei, Hongwei Yi, Mingyu Ding, Runze Zhang, Yisong Chen, Guoping Wang, and Yu-Wing Tai. Dense hybrid recurrent multi-view stereo net with dynamic consistency checking. In European Conference on Computer Vision, pages 674–689. Springer, 2020.

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Preparation

Camera parameters

```
extrinsic
E00 E01 E02 E03
E10 E11 E12 E13
E20 E21 E22 E23
E30 E31 E32 E33

intrinsic
K00 K01 K02
K10 K11 K12
K20 K21 K22
```

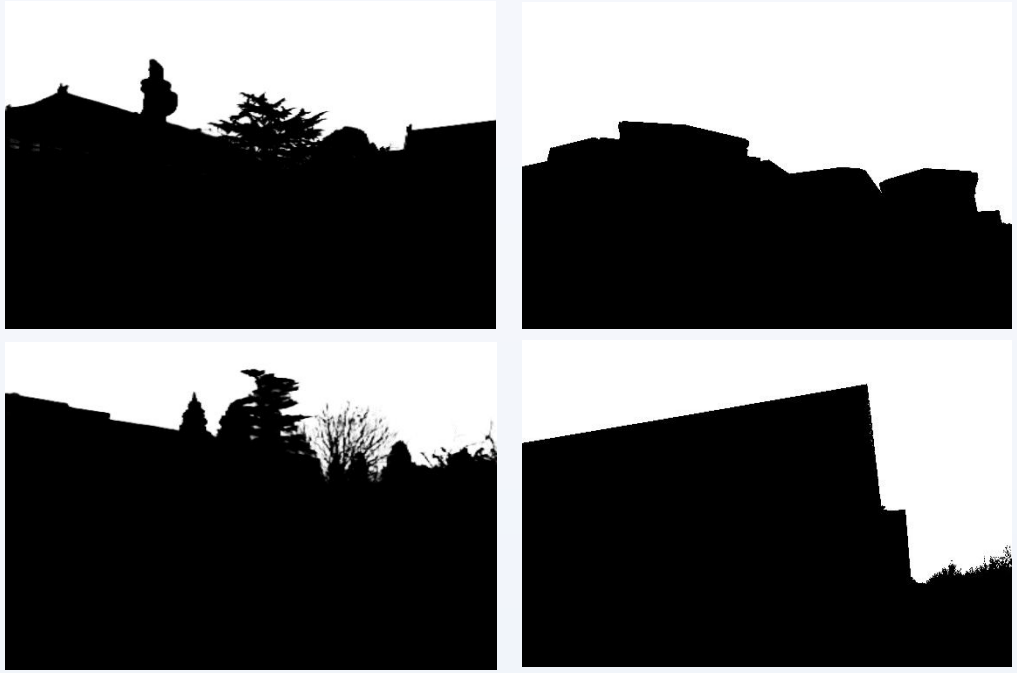
pair.txt

```
TOTAL_IMAGE_NUM
IMAGE_ID0
10 ID0 SCORE0 ID1 SCORE1 ...
IMAGE_ID1
10 ID0 SCORE0 ID1 SCORE1 ...
...
```

(depth range)
depth_min depth_inverval depth_num depth_max

Colmap SfM[4] is used to reconstruct the sparse point clouds. Then depth range and pair.txt are calculated by the sparse reconstruction for completing the camera files.

Semantics masks



DeepLab V3+[5] is used to segment images into **sky region and ground region**. We mask the sky region in white and the ground region in black.

[4] Johannes L Schönberger and Jan-Michael Frahm. Structure-from-motion revisited. In Proceedings of the IEEE conference on computer vision and pattern recognition, pages 4104–4113, 2016.

[5] L.-C. Chen, G. Papandreou, I. Kokkinos, K. Murphy, and A. L. Yuille. Deeplab: Semantic Image Segmentation with Deep Convolutional Nets, Atrous Convolution, and Fully Connected CRFs. TPAMI, 2017.

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Preparation

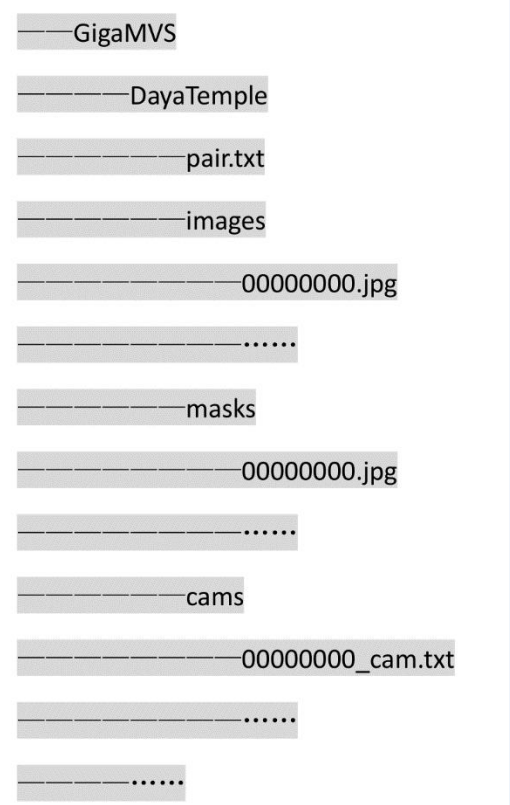
Requirements

Subject	Requirement
OS	Linux Ubuntu 20.04.5
GPU	24G Titan RTX at least
CPU	Intel Core I7+
Memory	256G+
Disk	4T
Cuda	>= 6.0
OpenCV	>=2.4
Cmake	3.25.1
Python	3.6

Settings

Subject	Requirement
Max resolution	6400
Patch size	21
Stages	4
View num	11
Iteration num	11
Hypotheses	8
Max view num (Fusion)	5
Depth threshold	0.03~0.09

File organization



It takes about one week to process all eight scenes.

Results

Leaderboard

#	Team	Members	Precision	Recall	F – score	Method	Code	Paper
1	ewrfcas		26.566373	22.35344	**22.33566**			
2	DTM3D		21.544648	**24.72914**	21.88166			
3	打赢baseline…		23.389852	19.22023	20.45153			
4	WeikangYou		22.684377	19.21984	19.99421			
5	CasMVSNet(…		28.75	17.73	19.20	CasMV…		
	Xiaodong Gu et al."Cascade Cost Volume for High-Resolution Multi-View Stereo and Stereo Matching".arXiv 2019.							
6	UCS-Net (ba…		28.30	17.77	19.02	UCS-Net		
	Shuo Cheng et al."Deep stereo using adaptive thin volume representation with uncertainty awareness".CVPR 2020.							
7	算法cj		23.446456	17.03879	18.58486			
8	COLMAP (ba…		**40.57**	13.14	17.90	COLMAP		
	Johannes Lutz Schönberger and Jan-Michael Frahm."Structure-from-Motion Revisited".CVPR 2016.							

Our method rank 2nd on Track Reconstruction

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Tricks

- **Precision & Recall Balance +1.0**

$$F(d) = \frac{2P(d)R(d)}{P(d) + R(d)}.$$

In order to get a high F-score, Precision or Recall should not be too low.

- **Remove useless views +0.1**

- **Point cloud filtering +0.5**

We use Backbone point clouds sampled on the buildings to automatically crop the final results.

- **Point cloud complement +0.2**

We merge Colmap points with high precision and low recall to complete our results.

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Conclusion

- Our method took the **second place** using a multi-scale patchmatch based framework, in which **multi-scale** feature matching, **view selection** and dynamic/semantic **fusion algorithms** play a key role.
- We‘ve tried some deep learning methods, but they don’t work well and can‘t produce high-resolution depth maps. However, theoretically, **learning based MVS methods** are expected to achieve better results.

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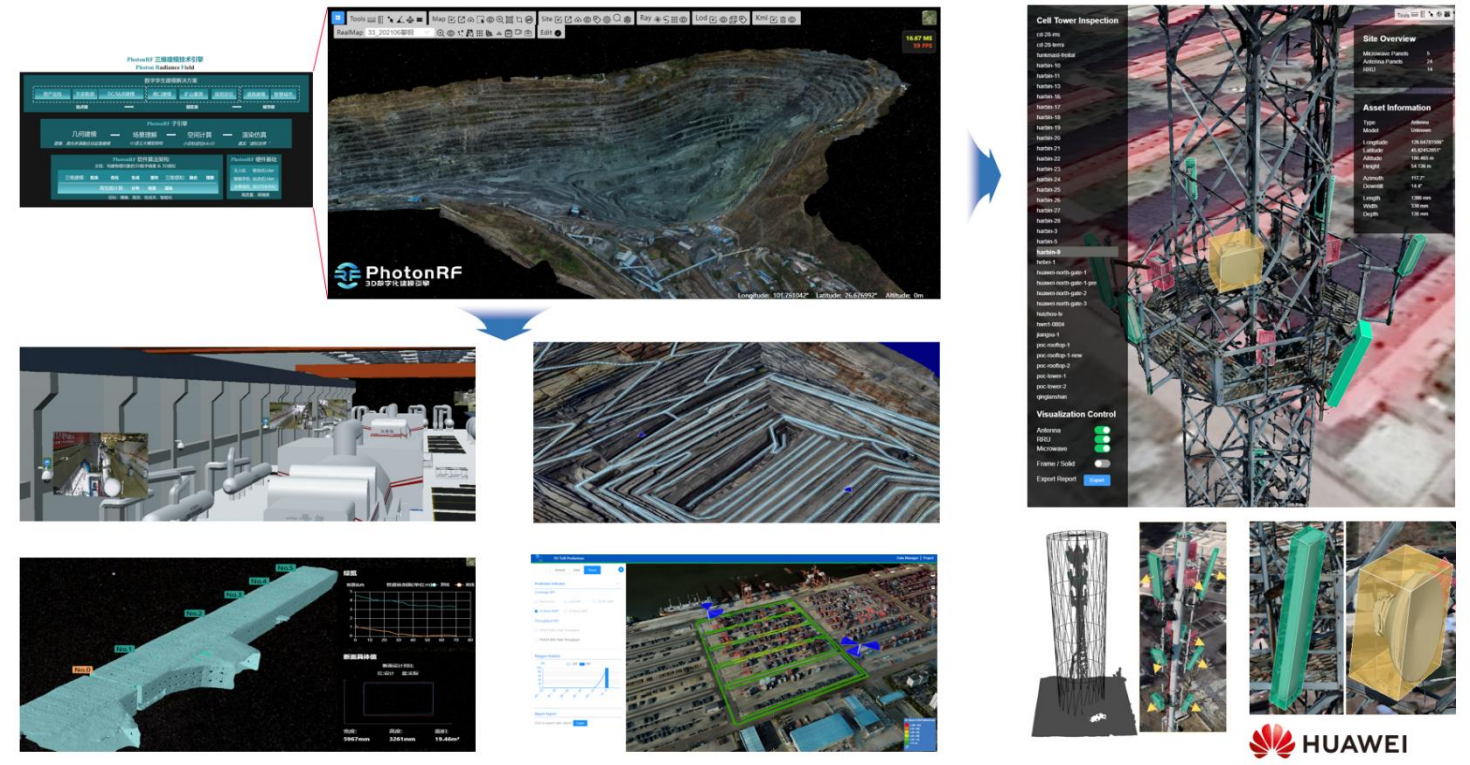
Invitation

Digital Twin Lab, Huawei



Our team focus on cutting-edge technology research and engine development of **image/LiDAR 3D reconstruction** and **2/3D semantic understanding** for solving technical problems such as **environment 3D modeling** and perception in **5G network simulation**.

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Welcome to join us!

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THANKS !