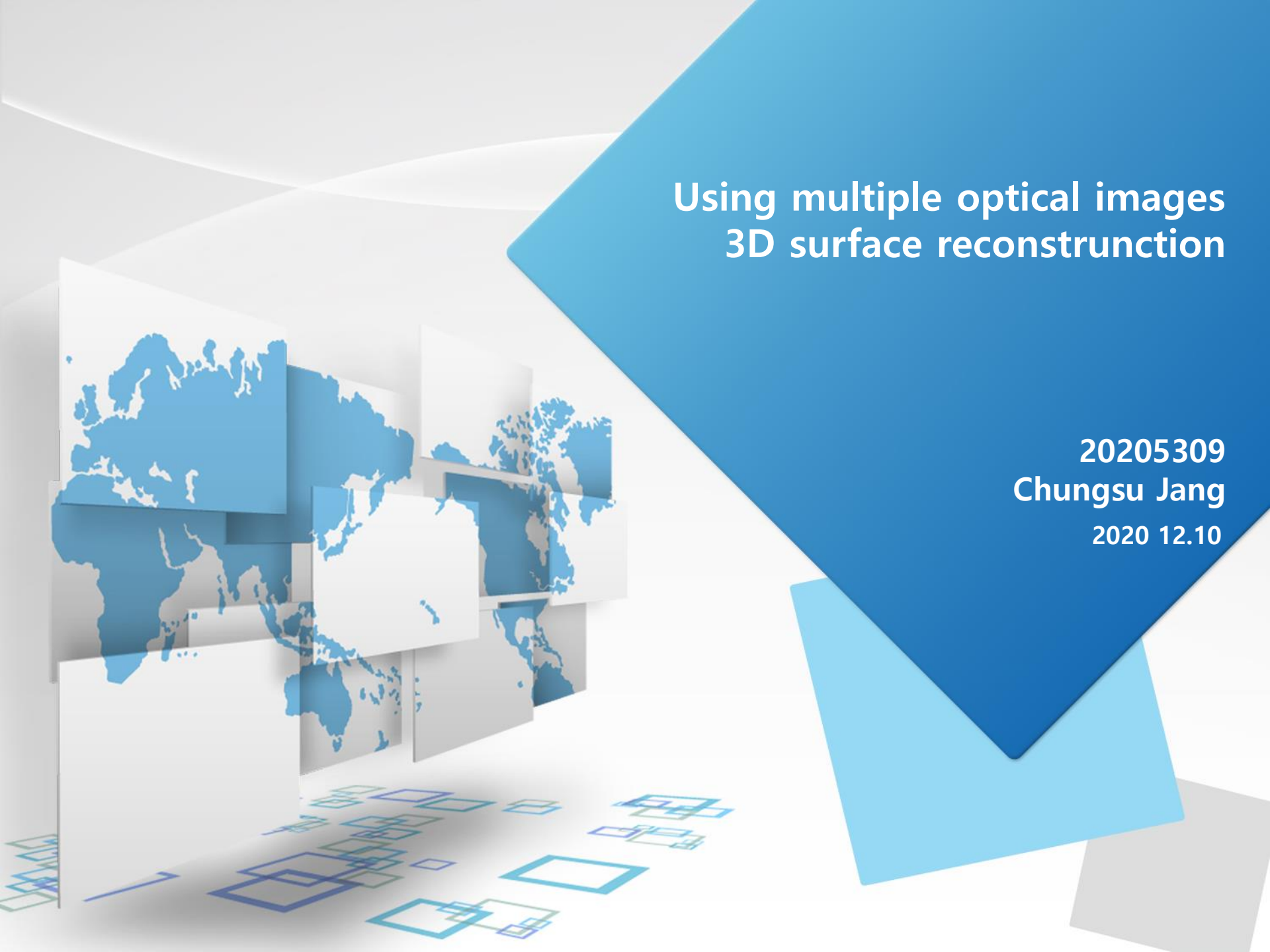


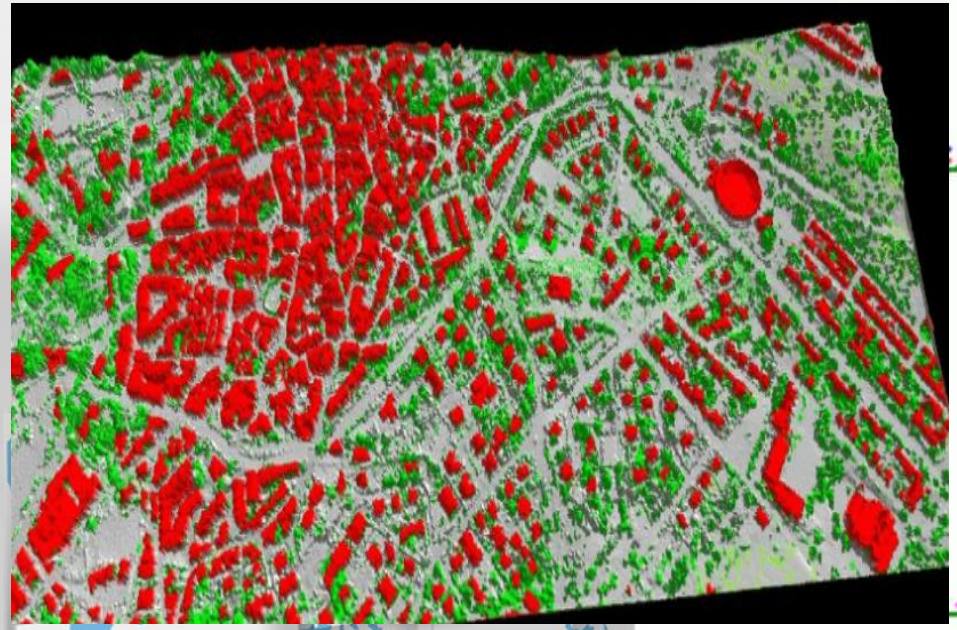
Using multiple optical images 3D surface reconstrunction

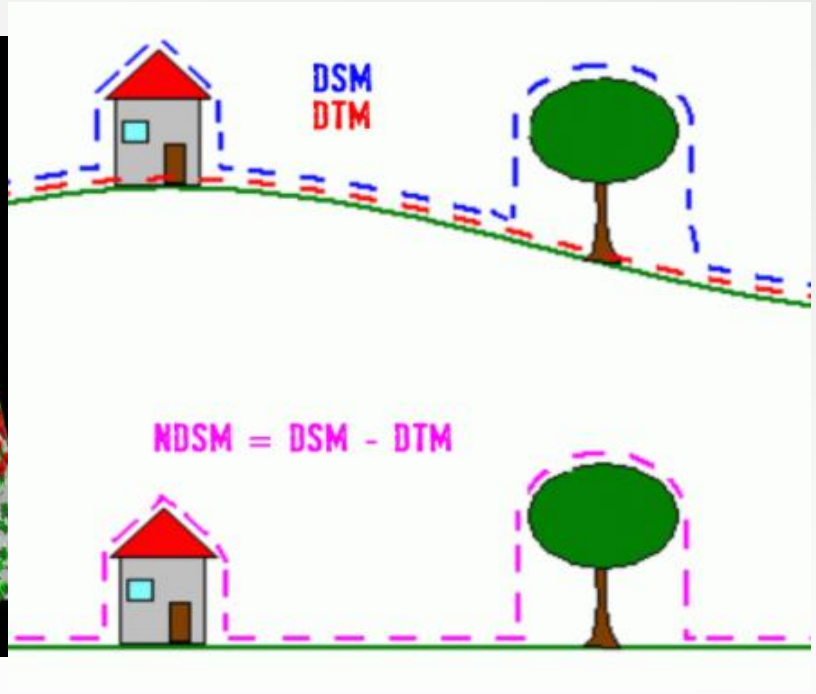
20205309
Chungsu Jang

2020 12.10

Contents

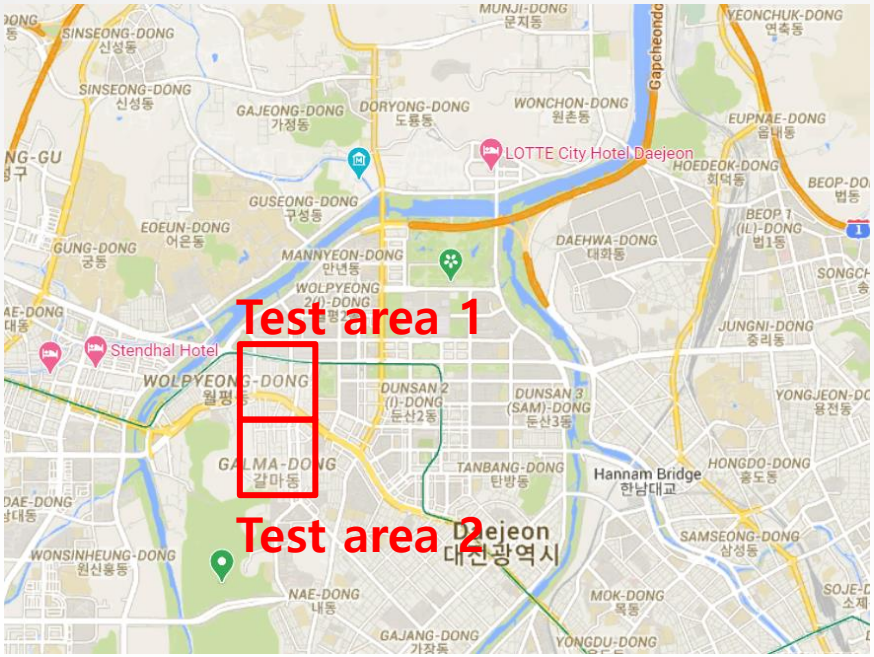
DSM(Digital Surface Model)





Analysis Data characteristics
3D dense points obtained using satellite imagery and SGM(Semi Global Mapping) matching technique

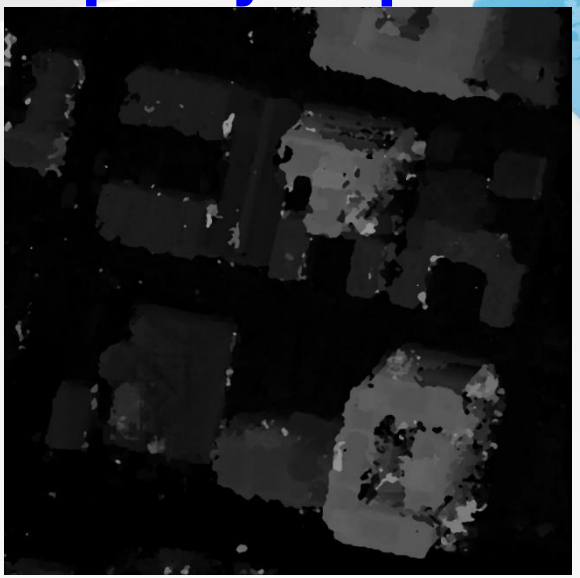
Korea Daejeon, WorldView3 Satellite



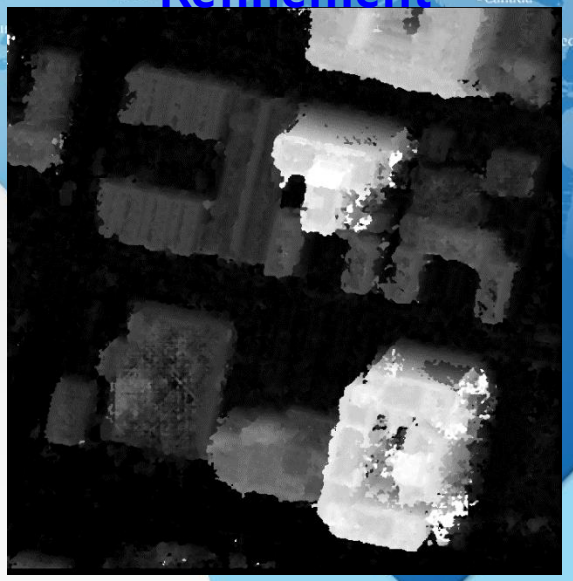
Problem Derivation through Analysis Data characteristics

Area 1(Daejeon) : Disparity Maps

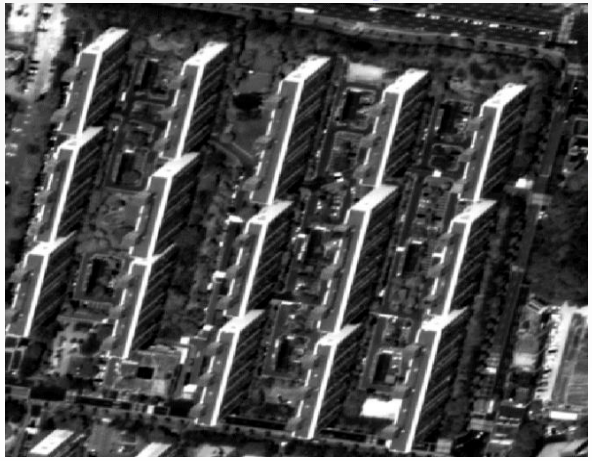
`block_size = 15`

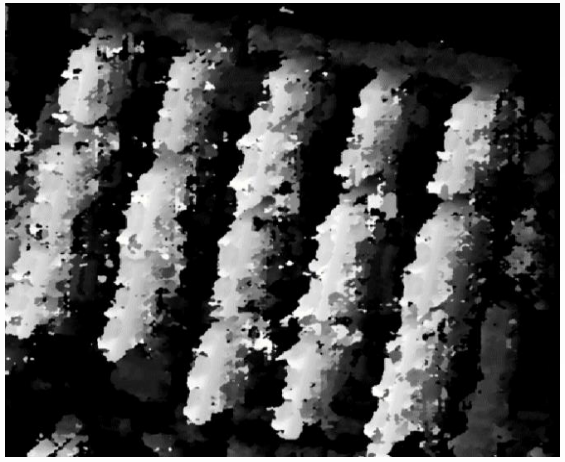


Refinement

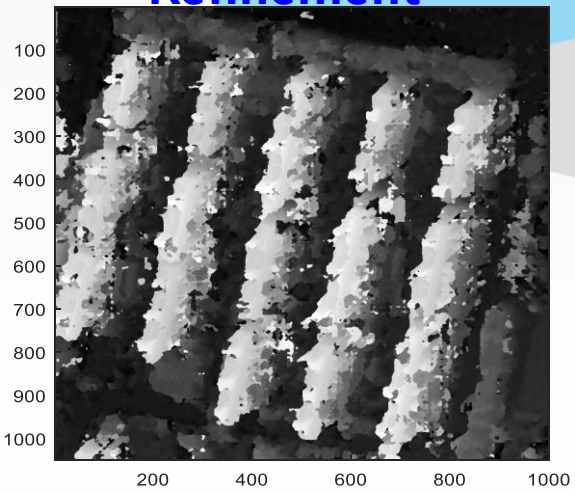


Area 2(Daejeon) : Disparity Maps





Refinement



- All Census & MI data : noise vertical range ~ 2 m, Many miss-matching points

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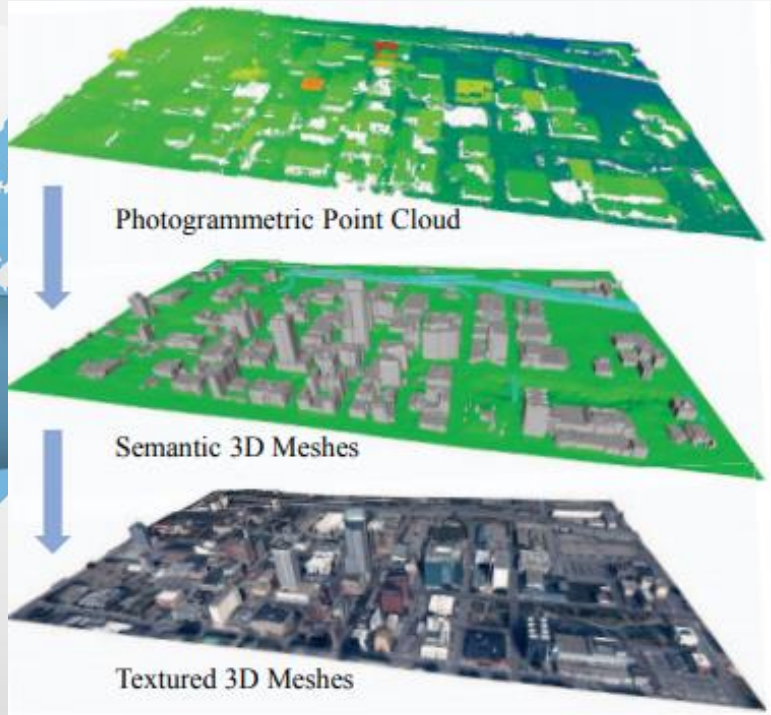
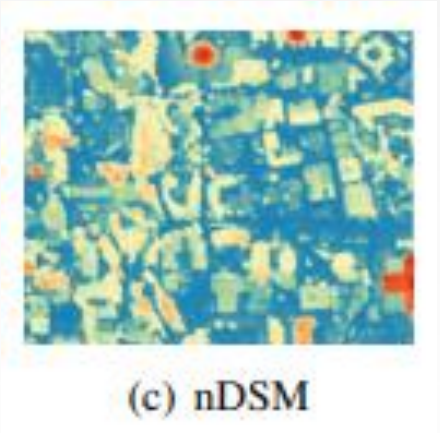
- Introduction
- Related Works
- Approach & Experiment
- Conclusion
- Q&A

Related Works

- Urban 3D reconstruction
  - Urban Semantic 3D reconstruction from Multiveiw Satellite Imagery, CVP R 2019



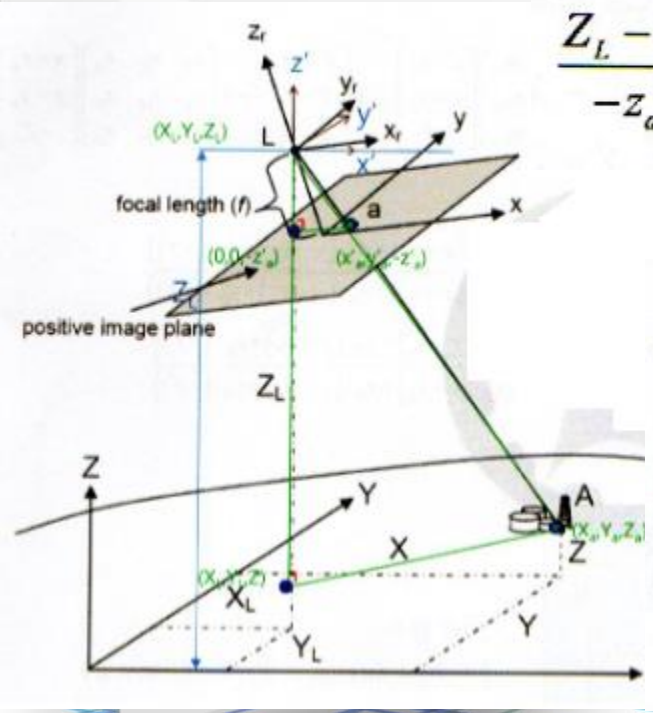


(c) nDSM

Related Works

- Geo referencing
  - mapping image pixels to global coordinates, photometry

R : RPC(The rational polynomial coefficient)



$$\frac{Z_L - Z_a}{-z_a'} = \frac{X_a - X_L}{x_a'} = \frac{Y_a - Y_L}{y_a'}$$

$$x = x_p - f \cdot \frac{(r_{11}\cdot(X-X_L)+r_{12}\cdot(Y-Y_L)+r_{13}\cdot(Z-Z_L))}{(r_{31}\cdot(X-X_L)+r_{32}\cdot(Y-Y_L)+r_{33}\cdot(Z-Z_L))}$$

$$y = y_p - f \cdot \frac{(r_{21}\cdot(X-X_L)+r_{22}\cdot(Y-Y_L)+r_{23}\cdot(Z-Z_L))}{(r_{31}\cdot(X-X_L)+r_{32}\cdot(Y-Y_L)+r_{33}\cdot(Z-Z_L))}$$

$$k\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} X - X_L \\ Y - Y_L \\ Z - Z_L \end{bmatrix}$$

GtoI()

$$[x, y] = fn(\omega, \phi, \kappa, X_L, Y_L, Z_L X, Y, Z)$$

$$k\begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}\begin{bmatrix} x - x_p \\ y - y_p \\ -f \end{bmatrix} = \begin{bmatrix} X - X_L \\ Y - Y_L \\ Z - Z_L \end{bmatrix}$$

ItoG()

$$\begin{bmatrix} x - x_p \\ y - y_p \\ -f \end{bmatrix} = 1/k\begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}\begin{bmatrix} X - X_L \\ Y - Y_L \\ Z - Z_L \end{bmatrix}$$

$$[X, Y] = fn(\omega, \phi, \kappa, X_L, Y_L, Z_L, x, y, Z)$$

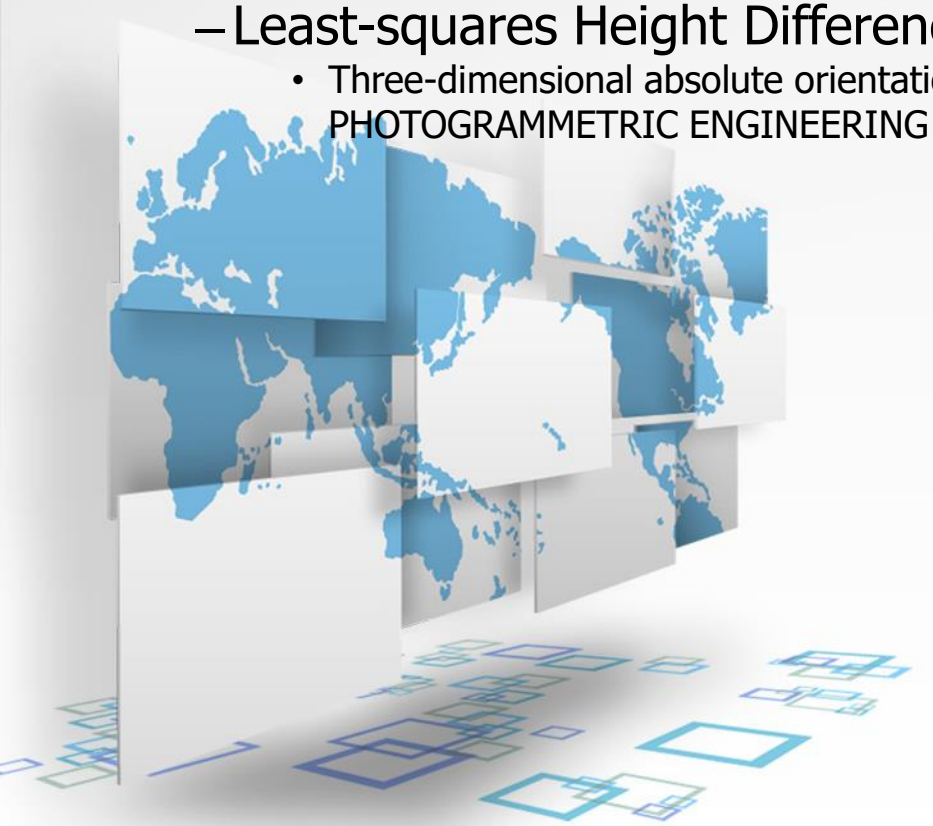
Ref: Introduction to Photogrammetry and Remote sensing, 1st Edition

Related Works

- Semi Global Matching(SGM)
  - Algorithm and architecture of disparity estimation with mini-Census adaptive support weight, IEEE Transactions on Circuits, 2006

Related Works

- Point cloud set matching
  - ICP(Iterative Closest Point)
    - A Method for Registration of 3-D Shapes. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 1992*
  - Least-squares Height Difference(LHD) Matching
    - Three-dimensional absolute orientation of stereo models using digital elevation models, PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, 1988



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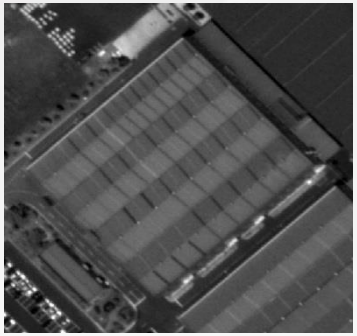
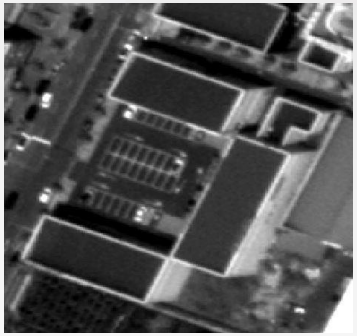
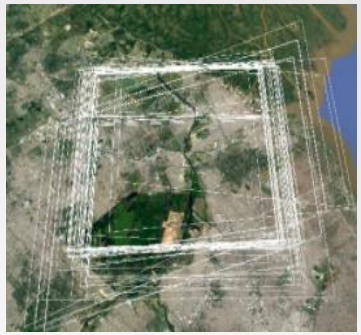
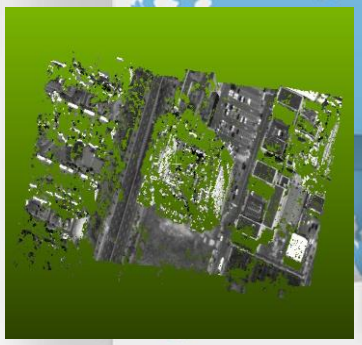
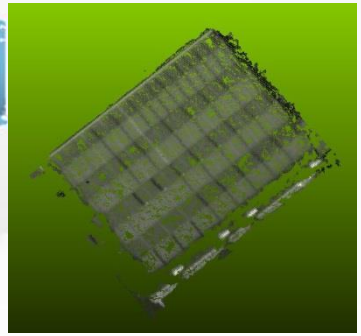
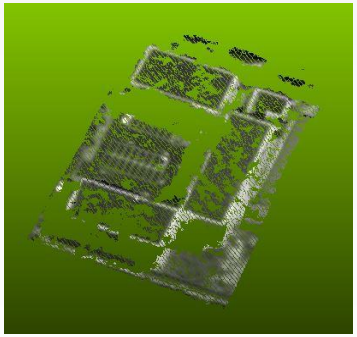
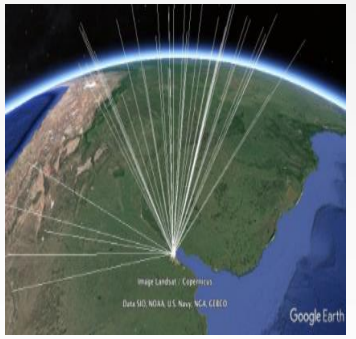
For 3D building shape restoration , approach

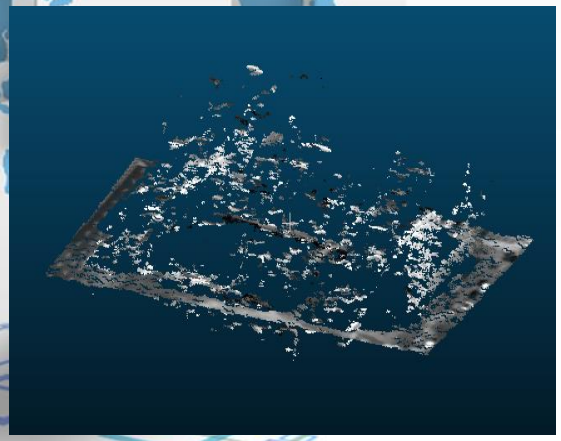


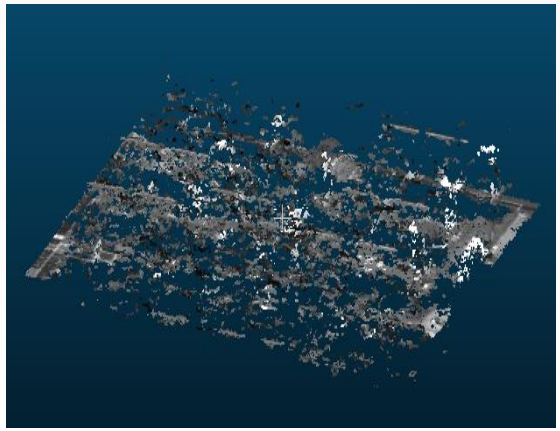





High-rise Building Reconstruction using Warped Images

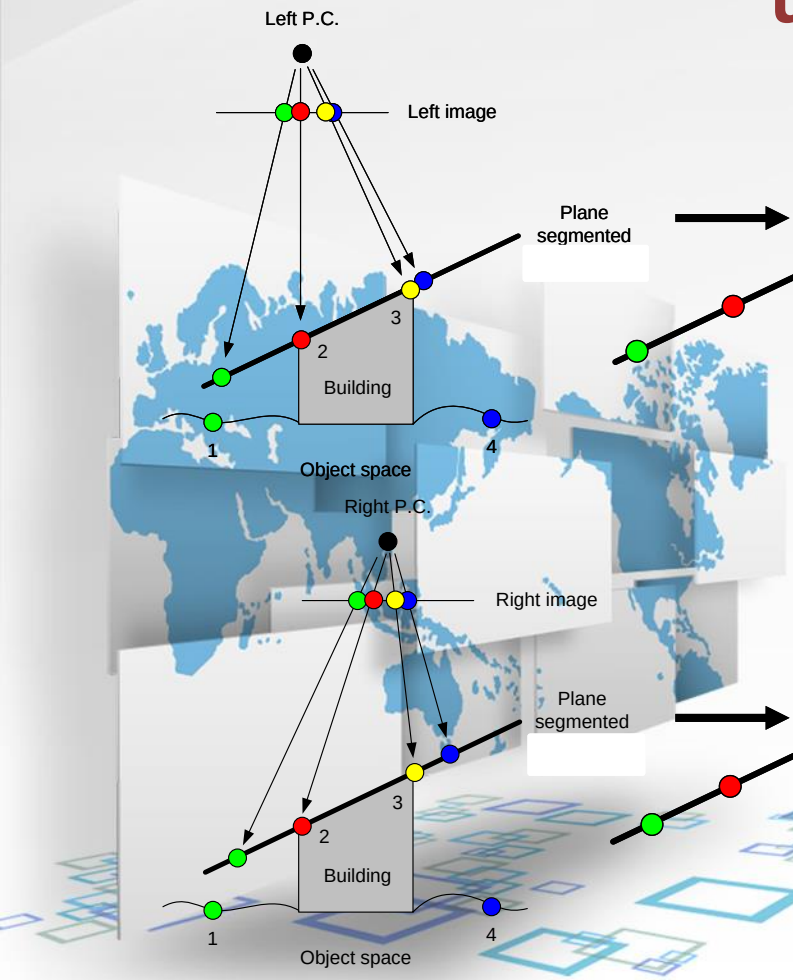
No way to recover these missing buildings?





Warped Image

When knowing information about the floor plan of the building



Projected points from image # 1

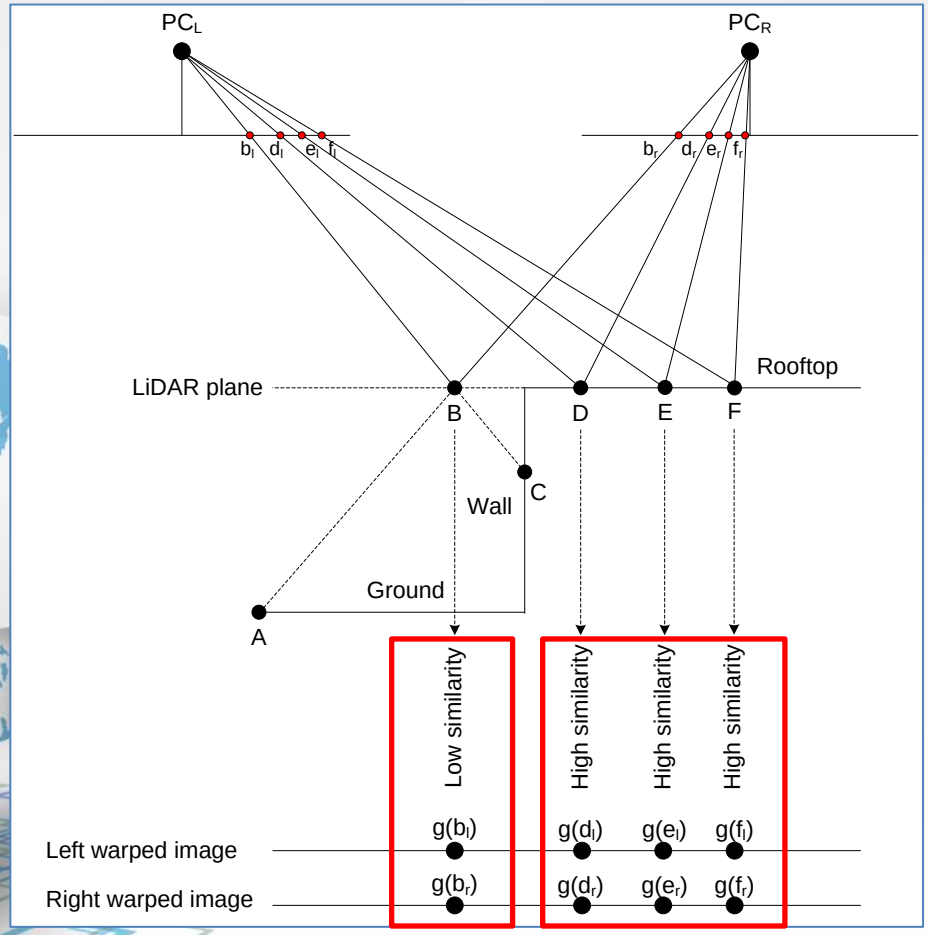
Projected points from image # 2

Alignment and color information in the building

Alignment and color information in the building

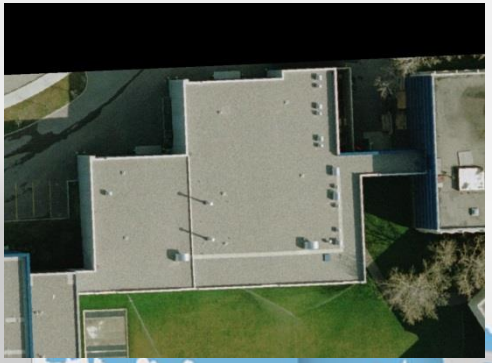
Warped Image

Two warped image comparison /
Inside and outside the building Similarity



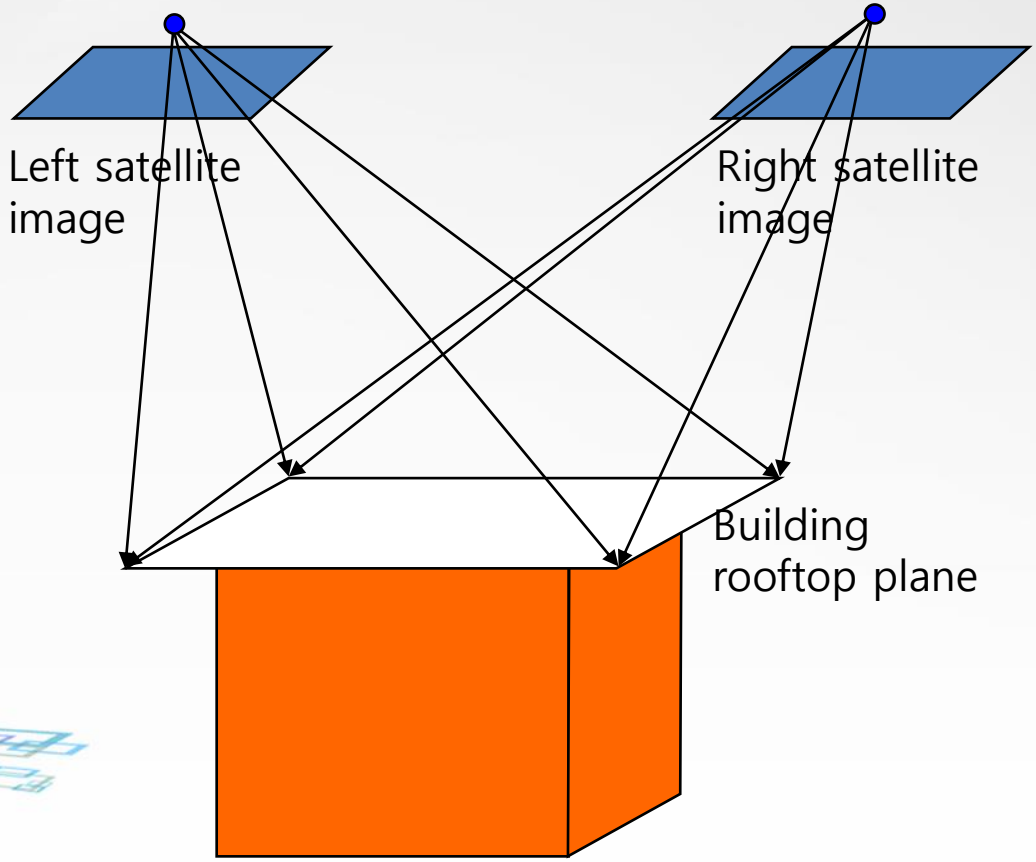
High-rise Building Reconstruction using Warped Images

- Similarity measure between two warped images and building height estimation

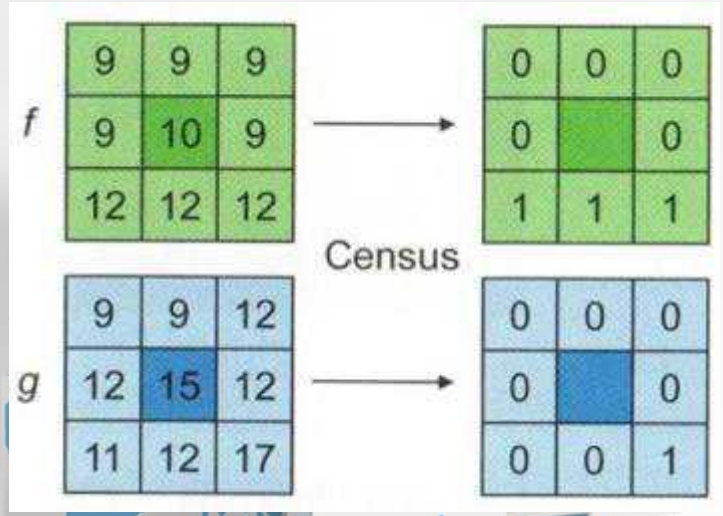


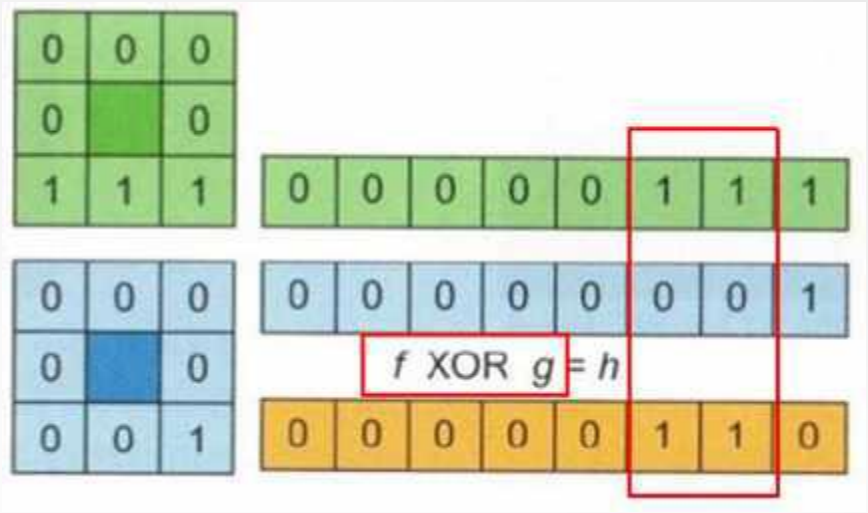
Left warped image

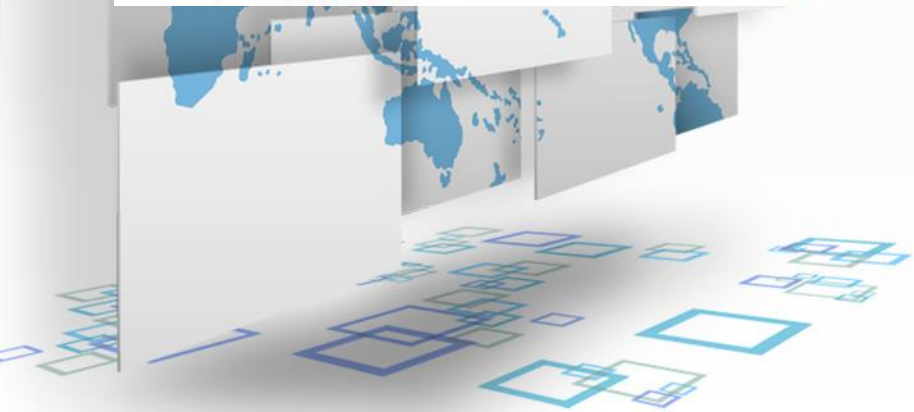
Right warped image



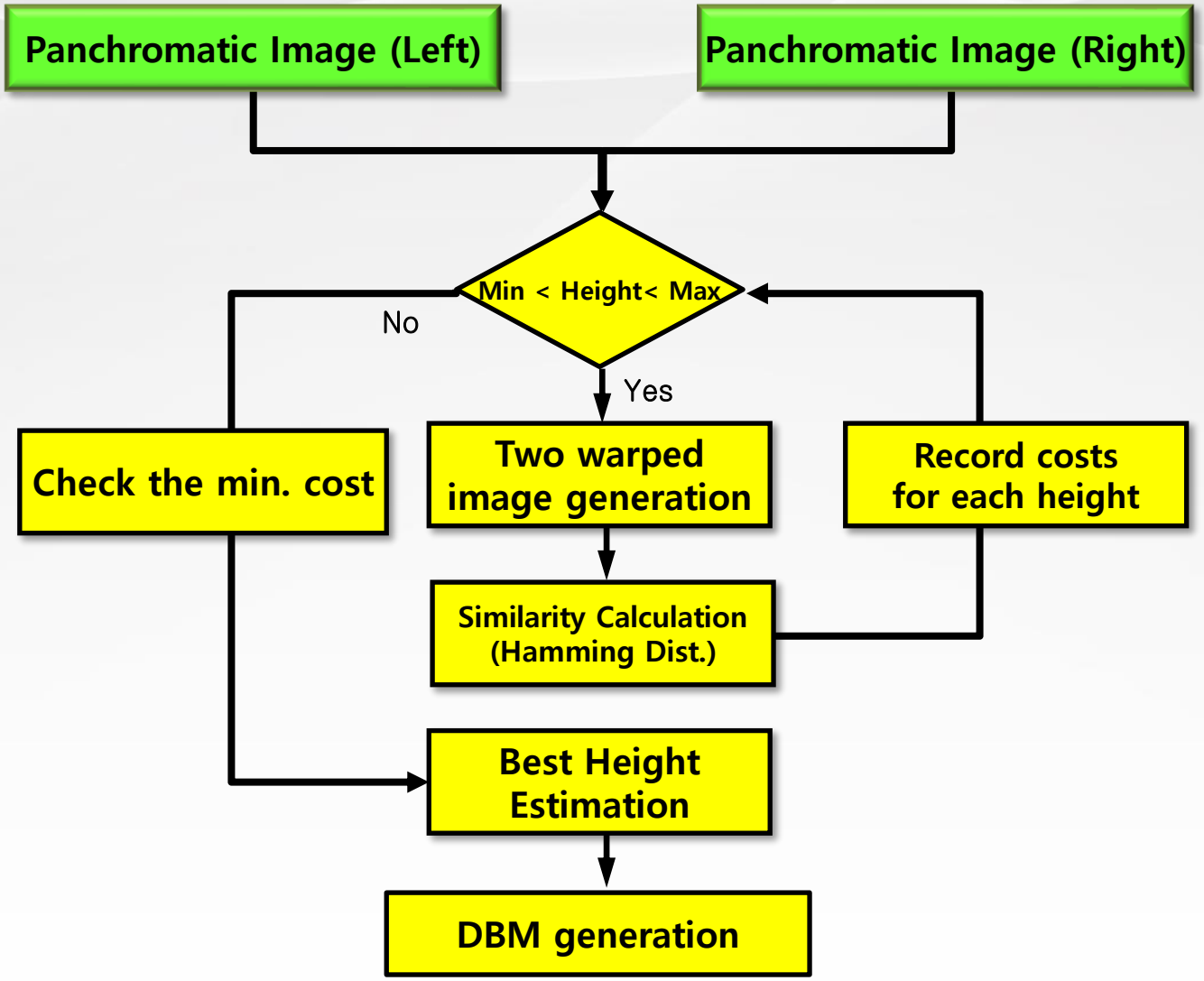
Similarity Check: Hamming distance



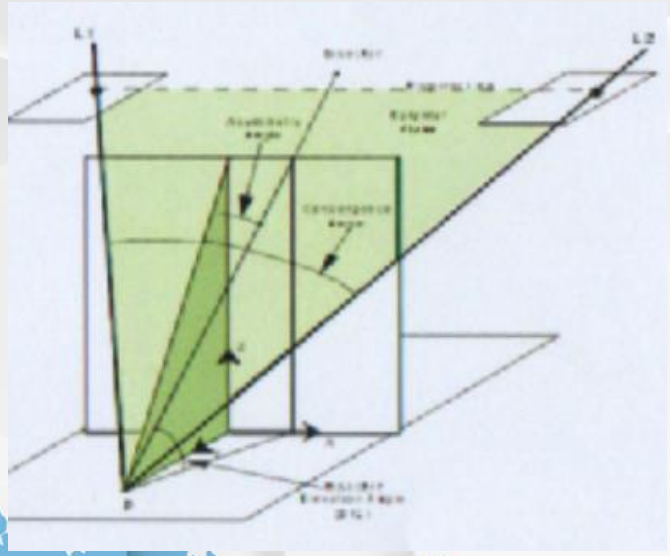




Proposed Workflow – 1st track approach



Best Views



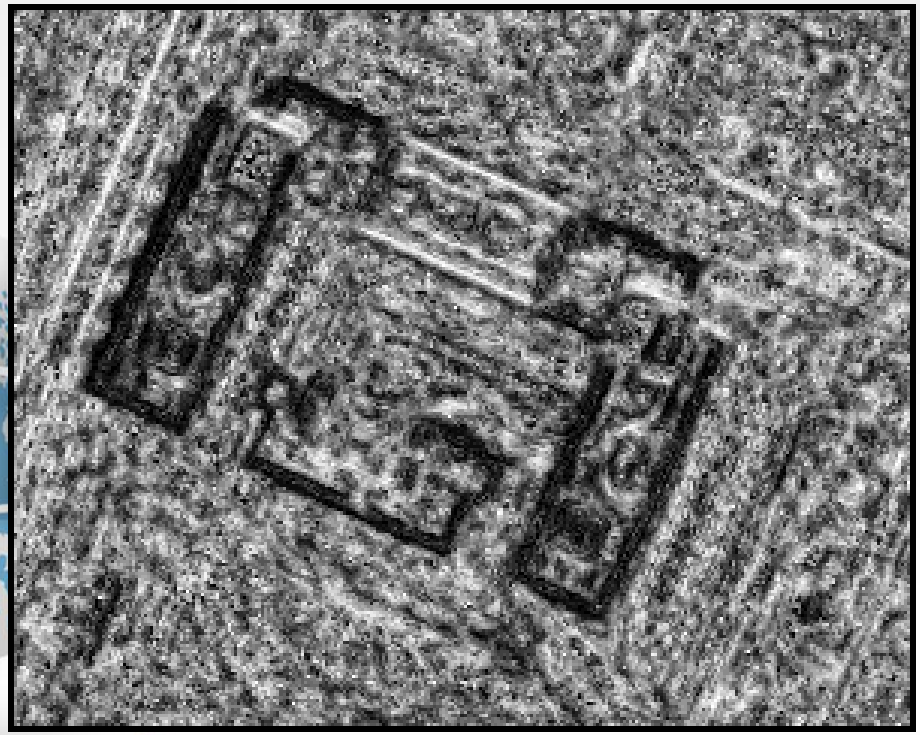
Three-dimensional geometric condition
Convergence Angle : 25~45
Bisector Elevation Angle : > 60
Satellite Azimuth Angle : <70
Satellite Azimuth Angle : <15

Similarity Check

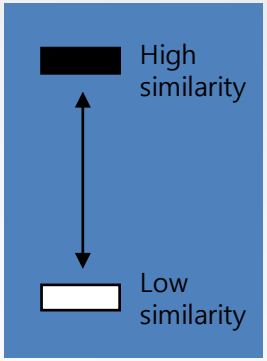
- High similarity measure at the correct height
- Low similarity measure at the incorrect height

Left warped image

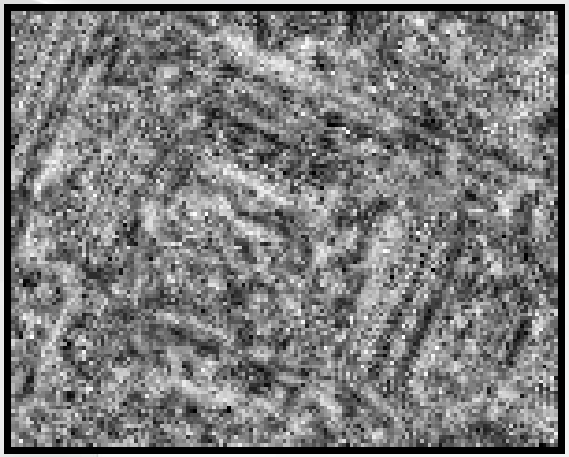
Right warped image



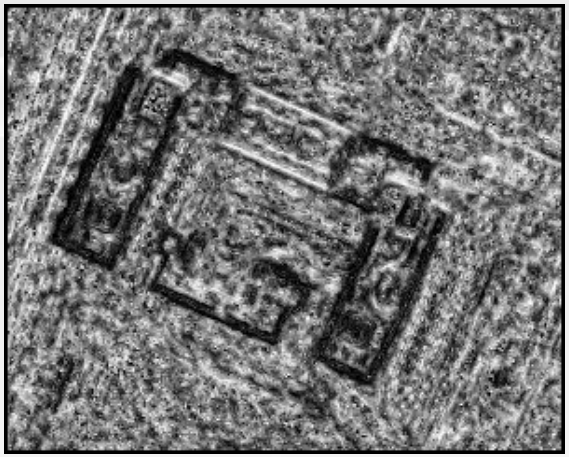
Similarity Measure Map



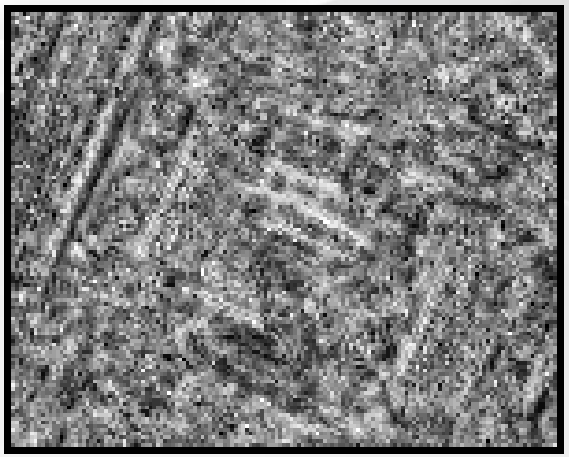
Test results



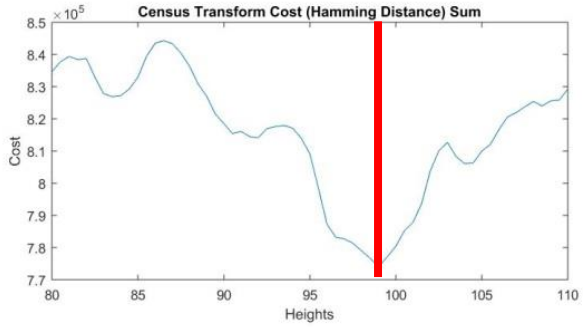
H : 81m

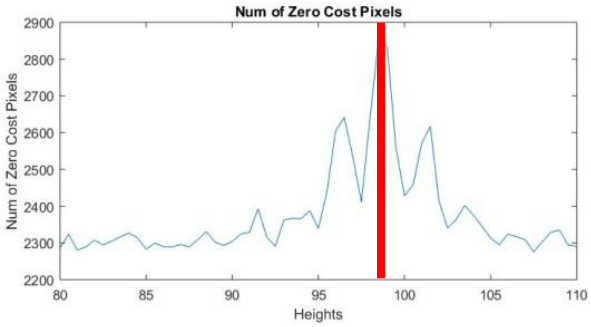


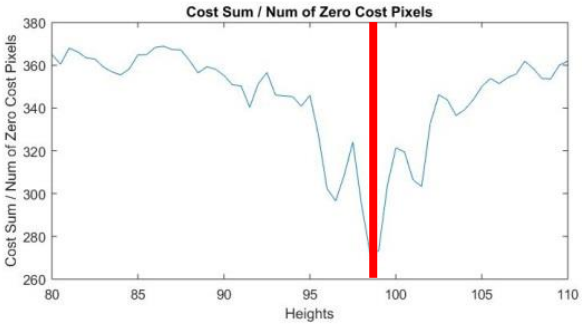
H : 99m



H : 107m

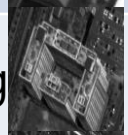
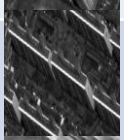






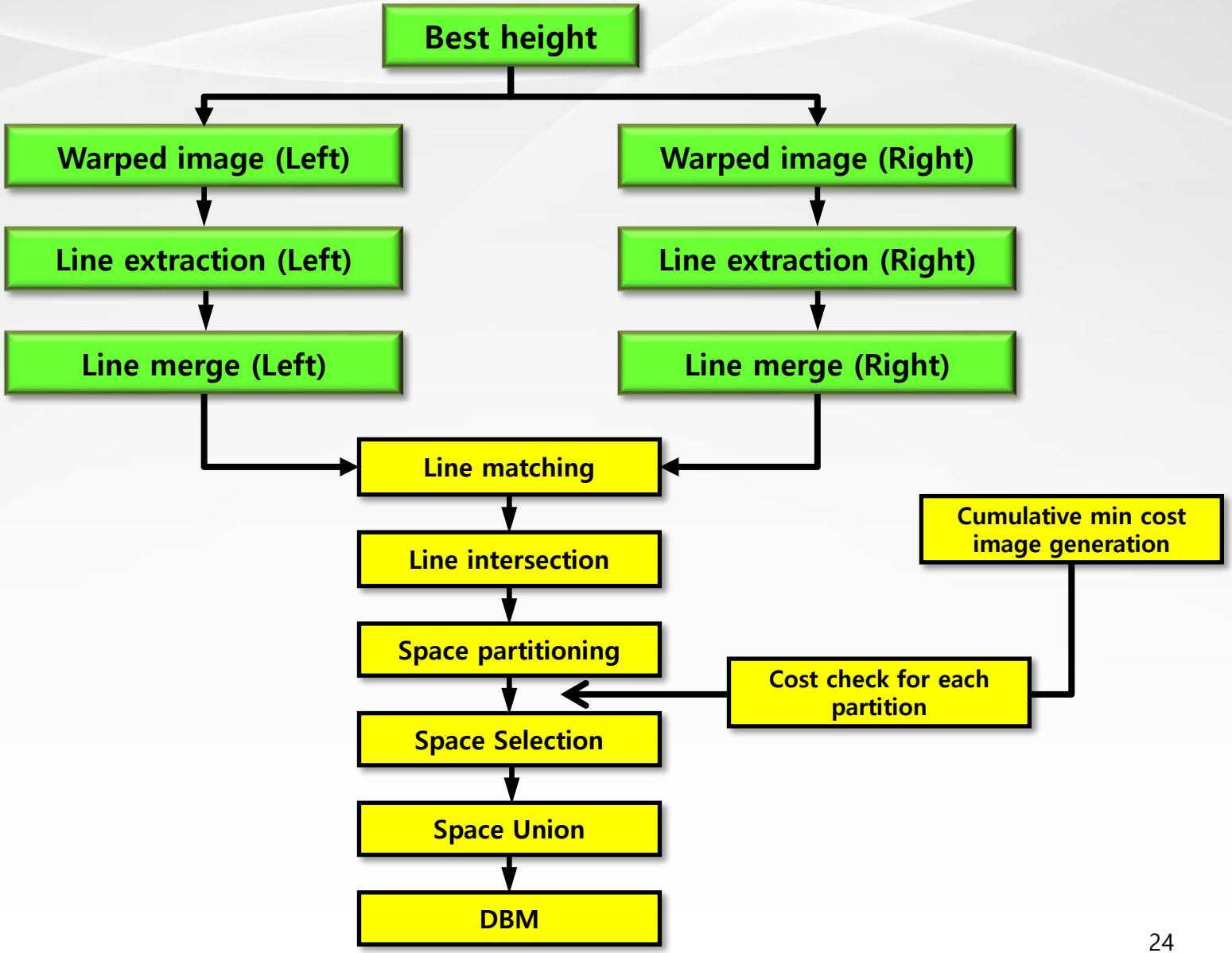
Best estimated Building Height : 99m at the min. cost

Test results

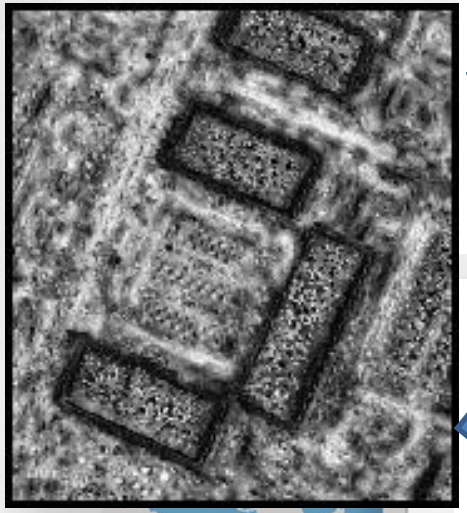
	Reference Height (m)	Estimated Height (m)	diff (m)
'ㄷ'type building 	72.61	72.50	0.11
'ㅁ'type building 	99.29	99.00	0.29
Apartment 	100.75	101.00	0.25
High building 	233.45	233.50	0.05
Low builidng– 1 	70.47	70.00	0.47
Low building– 2 	70.71	71.00	0.29

※ Reference height is extracted by intersection after manually measuring the same feature from left and right satellite images

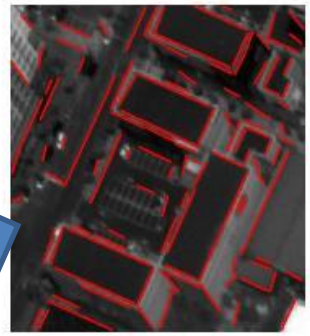
Using Warped image Outline and plane extraction method



Linear Information Extraction and Merge

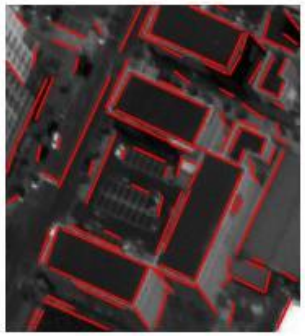


Best height estimation using similarity measure

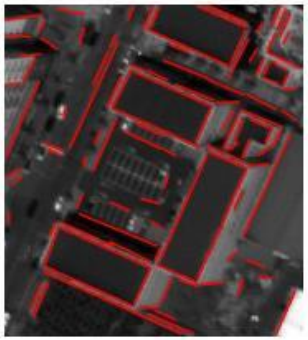


Line detection

Left warped image at the Best height

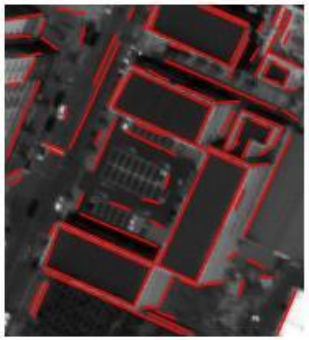


Line merge



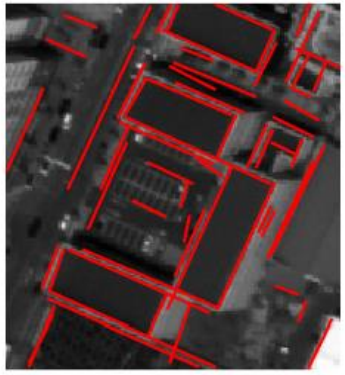
Line detection

Right warped image at the Best height

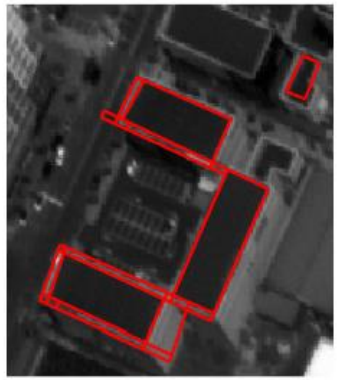


Line merge

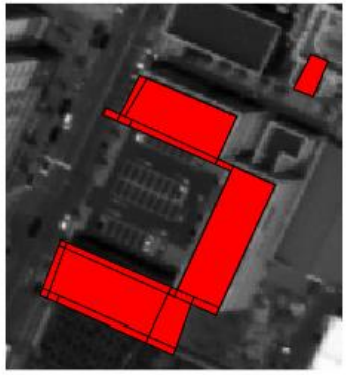
Matching, Intersection, Space partitioning and Building area selection



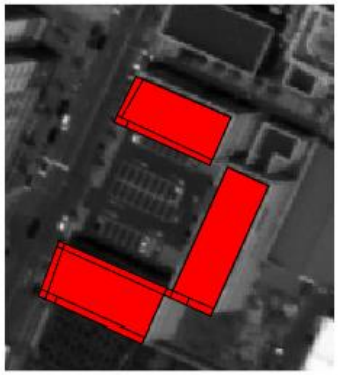
Line matching



Line intersection

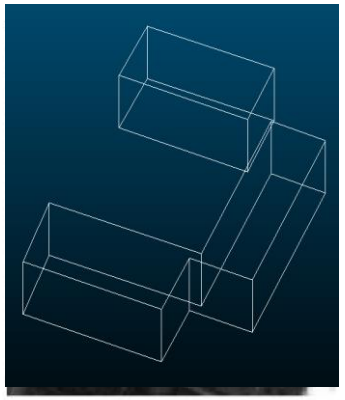


Space Partitioning



Space Selection

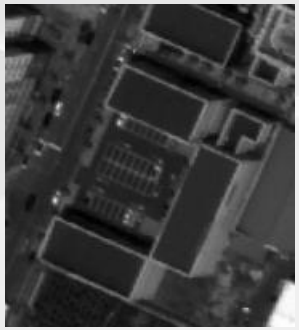
Space Union



DBM

Test results (two satellite images, Redundancy)

U type



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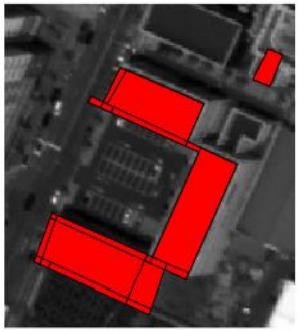
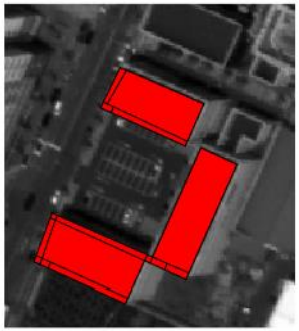


Space partitioning



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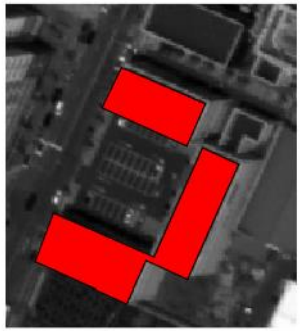
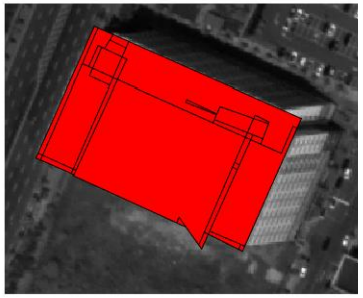


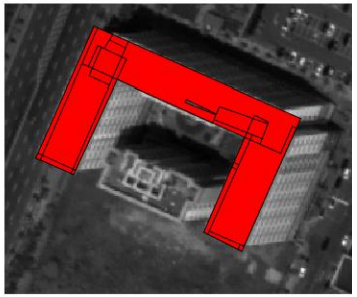
Space union

□ type

Image



Space partitioning



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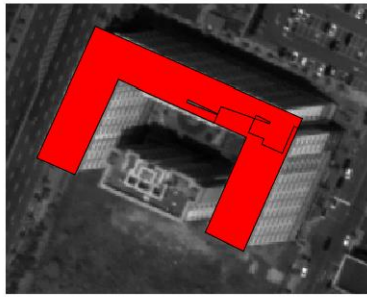
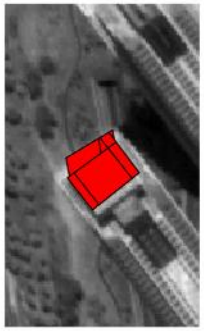


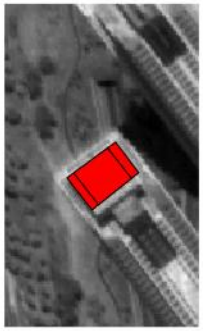
Space union

High

Image



Space partitioning



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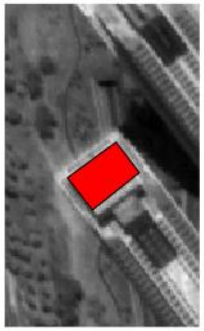
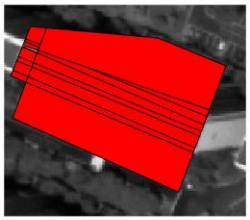


Space union

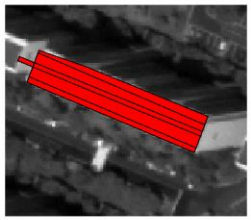
Test results (two satellite images, Redundancy)

Apartment

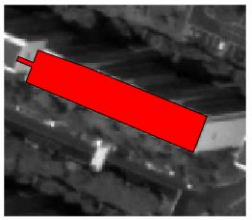
Image



Space partitioning



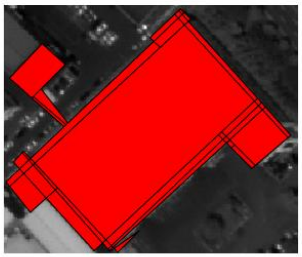
Space selection



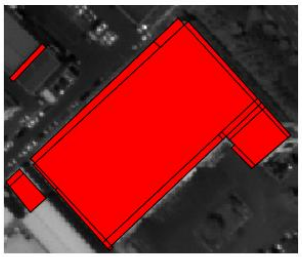
Space union

Low-1

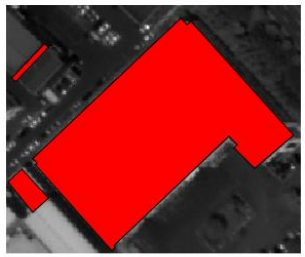
Image



Space partitioning

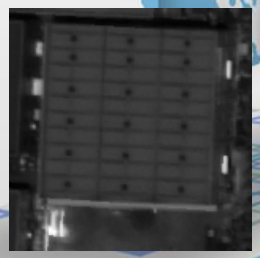


Space selection

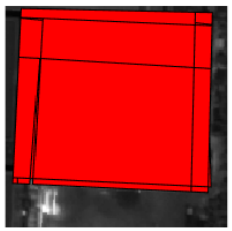


Space union

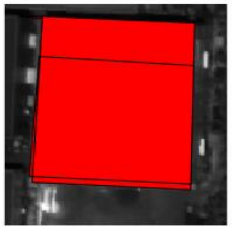
Low-2



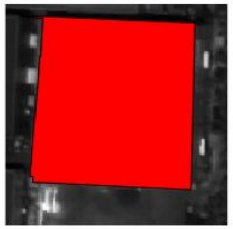
Image



Space partitioning



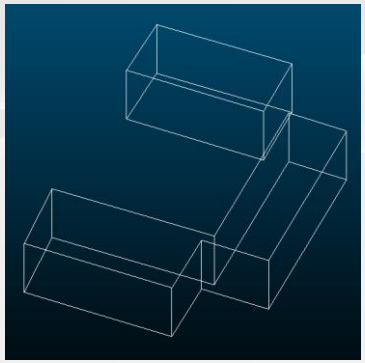
Space selection



Space union

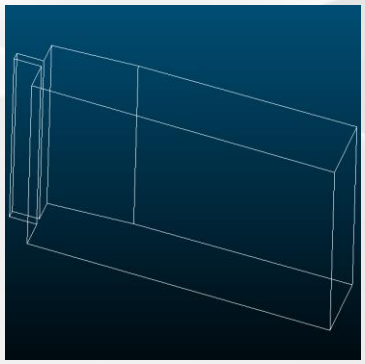
Test results (two satellite images, Redundancy)

U type



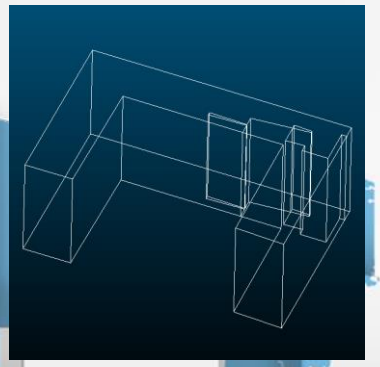
DBM

Apartment



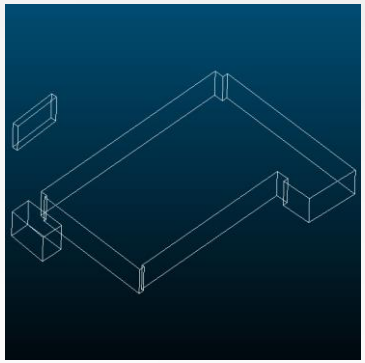
DBM

□ type



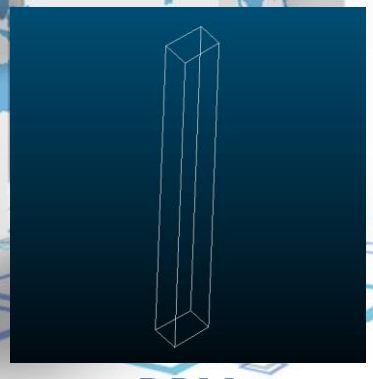
DBM

Low-1



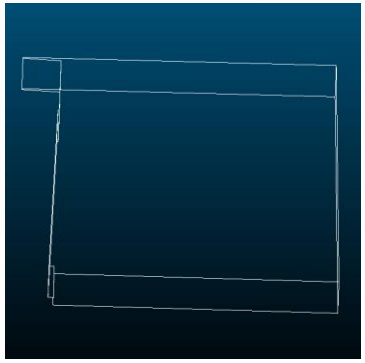
DBM

High



DBM

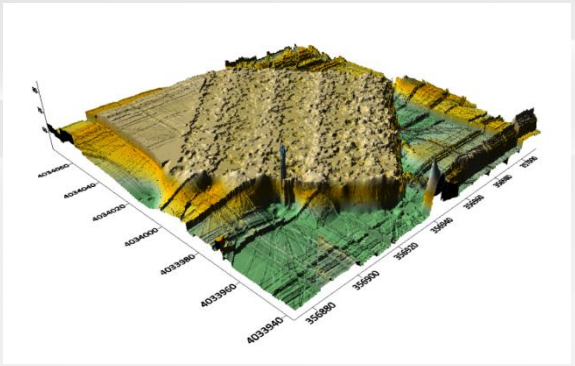
Low-2



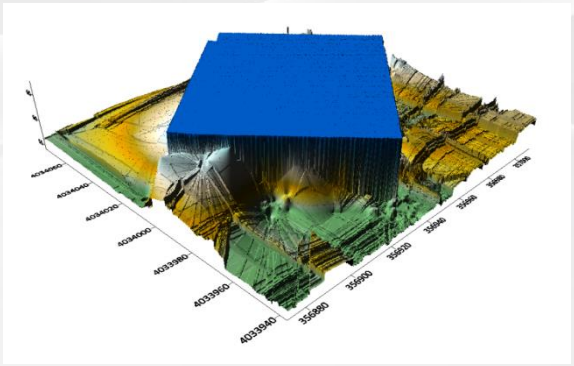
DBM

Test results (Improved DSM Generation)

Building 1

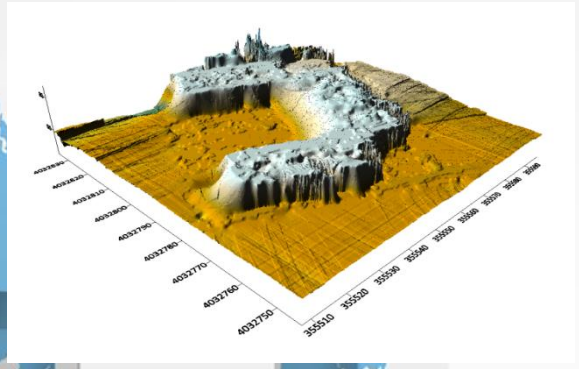


DSM from point cloud

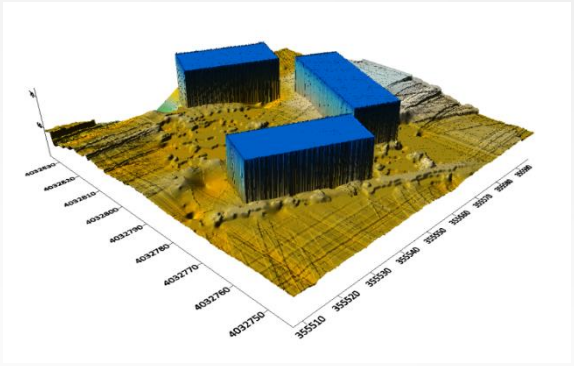


Improved DSM

Building 2

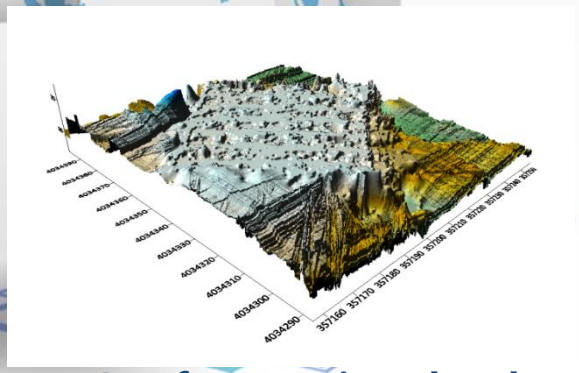


DSM from point cloud

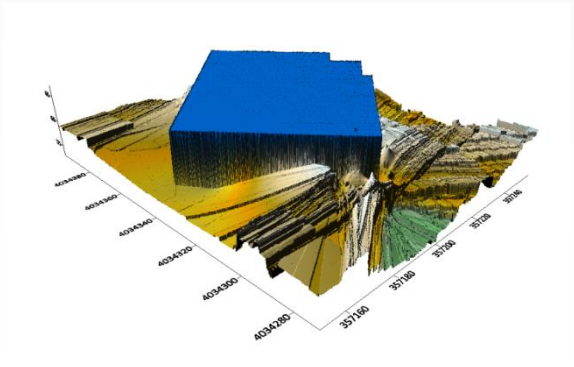


Improved DSM

Building 3



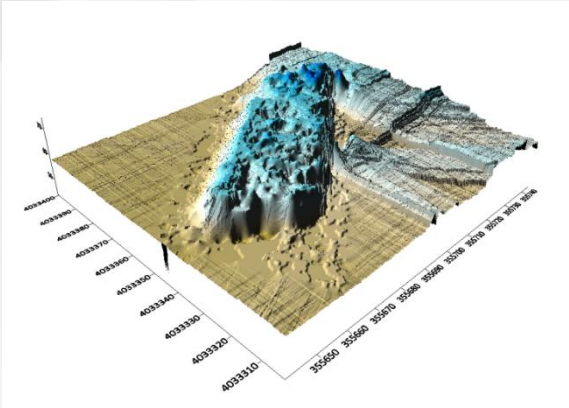
DSM from point cloud



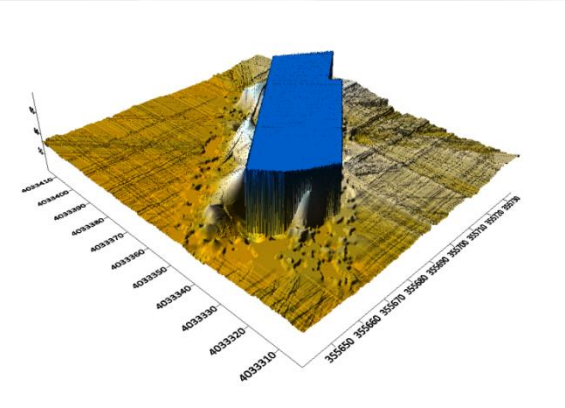
Improved DSM

Test results (Improved DSM Generation)

Building 4

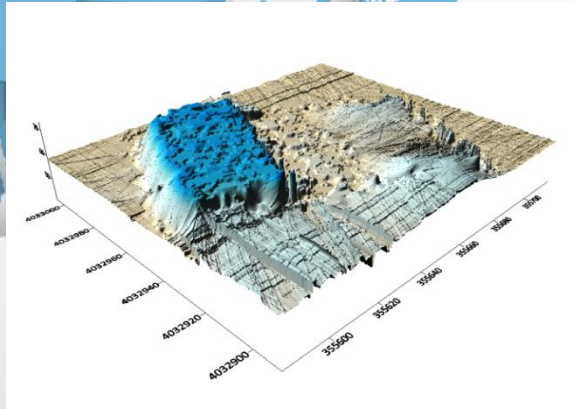


DSM from point cloud

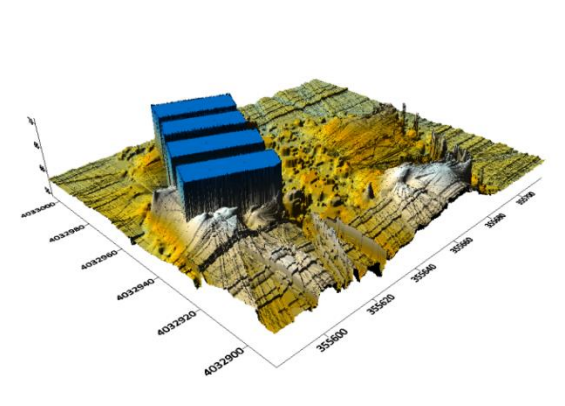


Improved DSM

Building 5

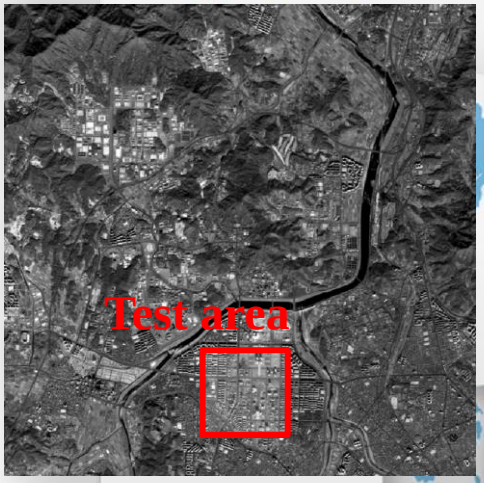


DSM from point cloud



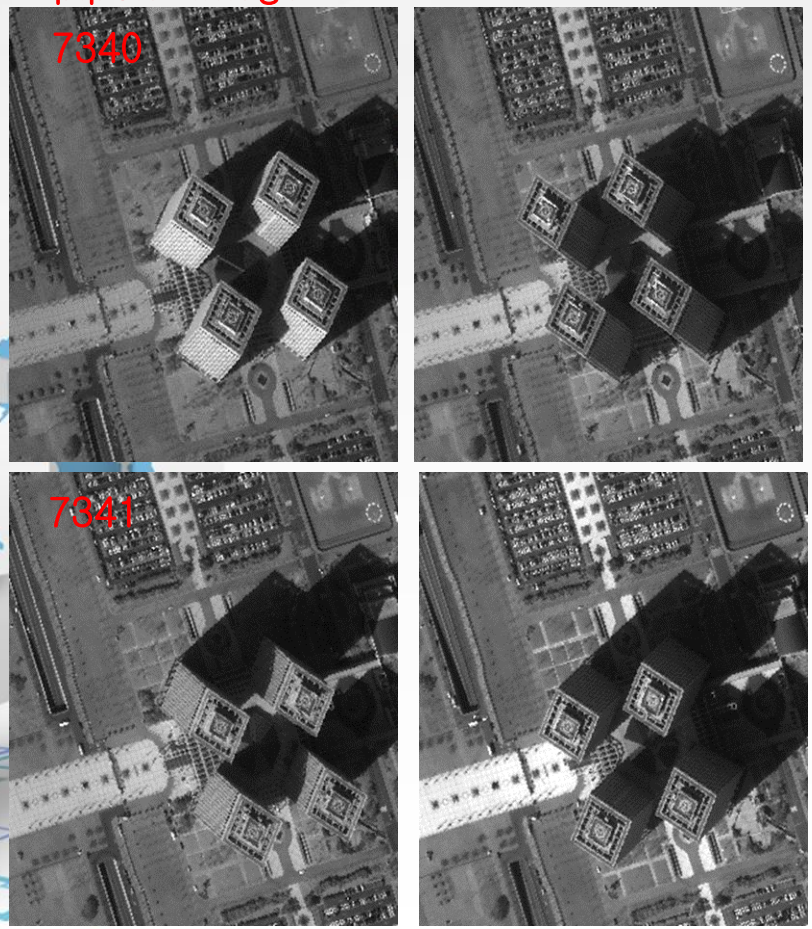
Improved DSM

Sensor Fusion



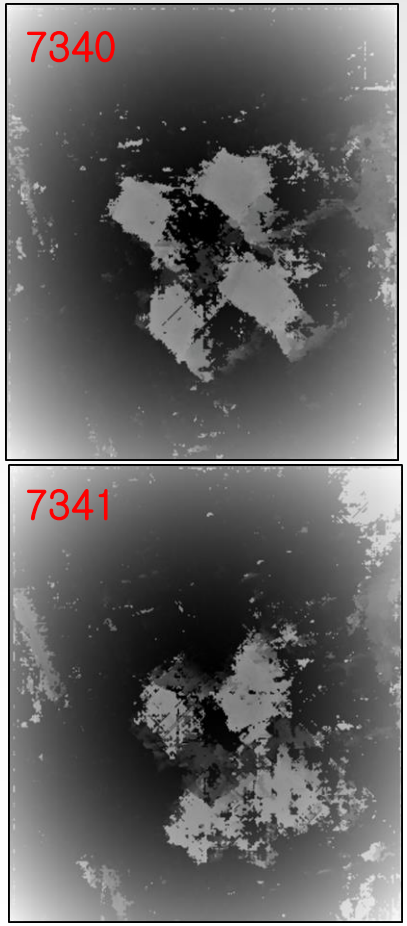
IKONOS-2

Epipolar Image



WV-3

SGM Disparity Map

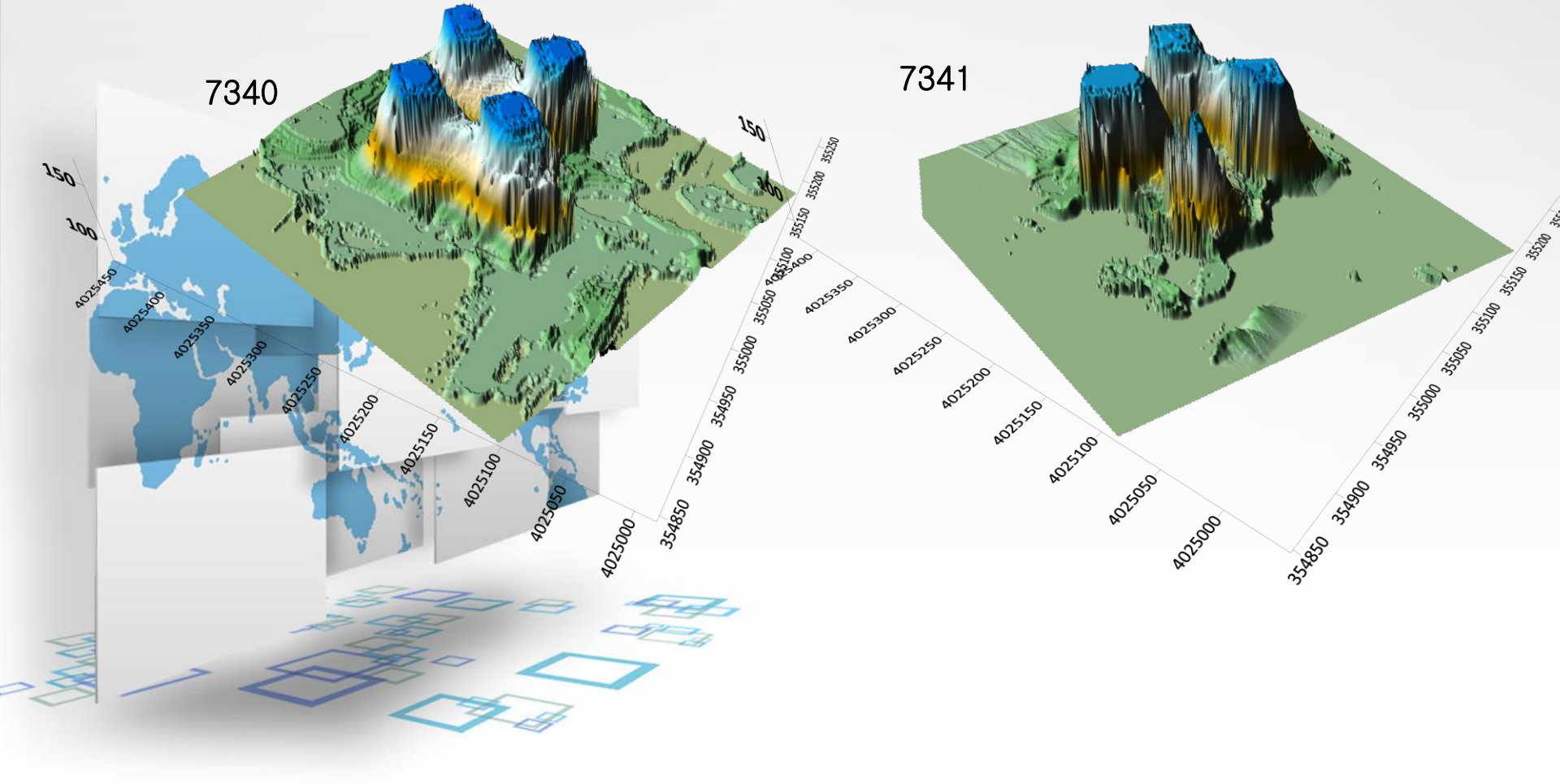


Sensor Fusion

DEM

IKONOS-2

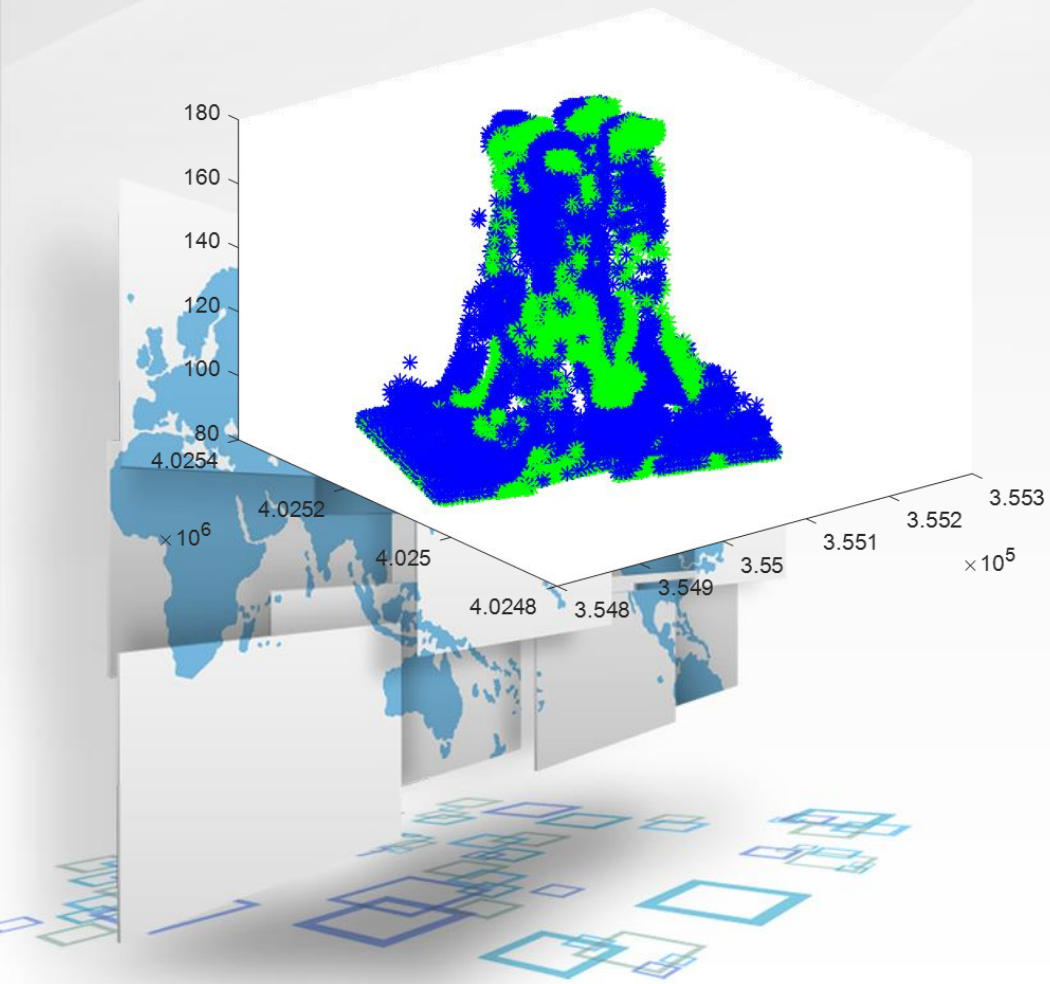
WV-3

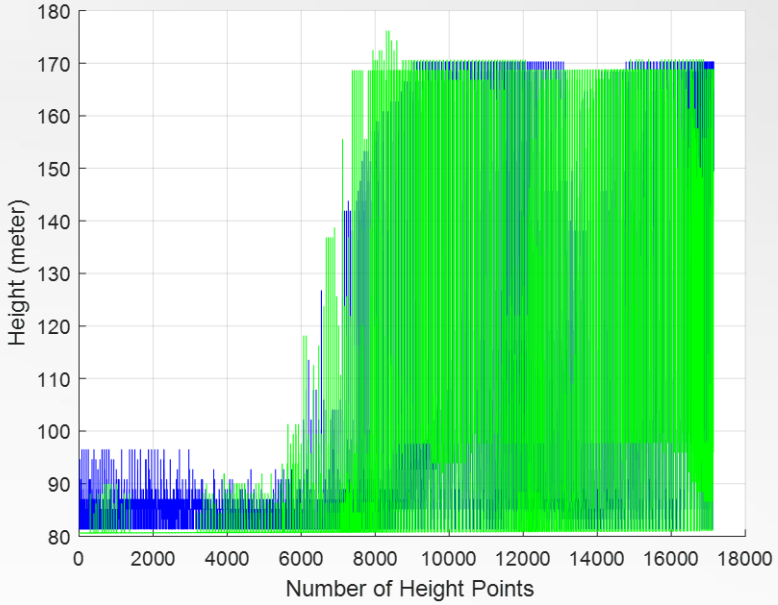


Sensor Fusion

Point Cloud Matching : Use 12,322 points

LHD Matching (reference)





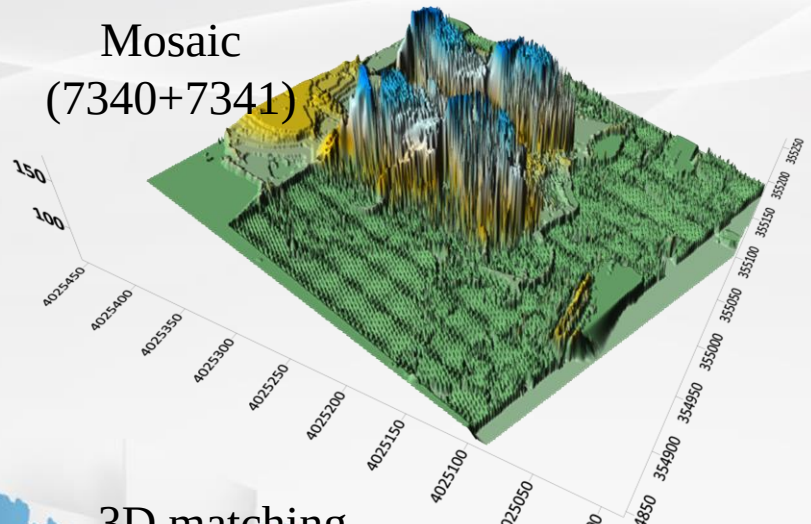
RMSE = 23.4m; Max = 89.1m

Sensor Fusion

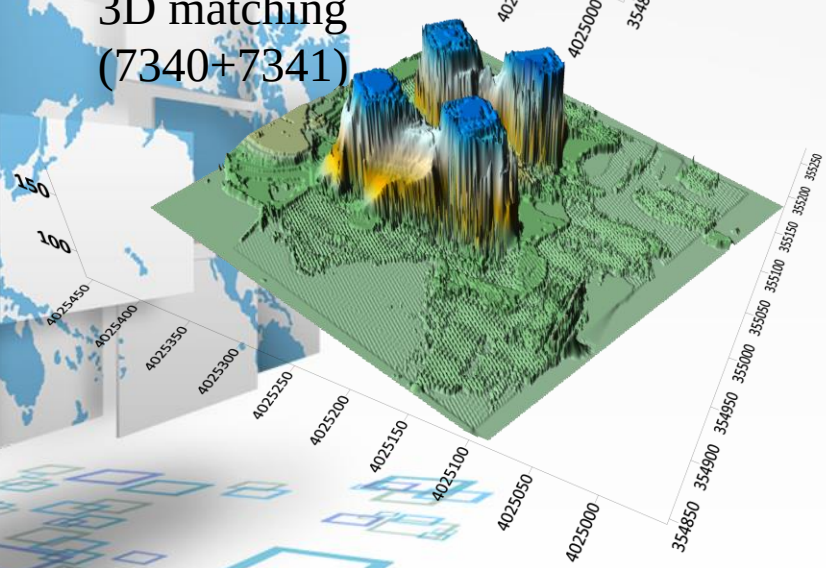
Point Cloud

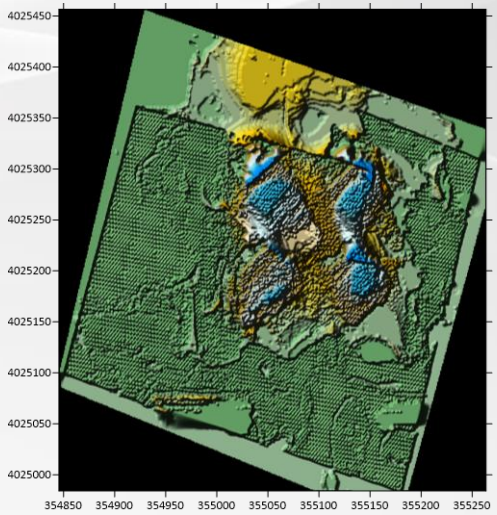
Matching

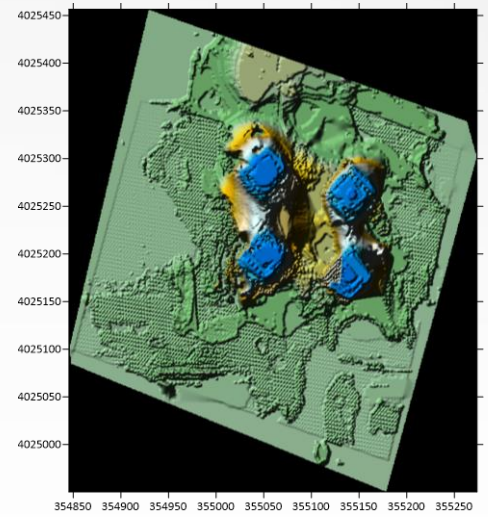
Mosaic
(7340+7341)



3D matching
(7340+7341)







Contents

- Introduction
- Related Works
- Approach & Experiment
- Conclusion
- Q&A

Conclusion

- Suggest to generate 3d surface model from several sat ellite image
- Show you the generated 3d model surface, visually
- Limit : Completeness? / Accuracy?

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Thank you

Q & A