QinLab
Geospatial Data Analytics

THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

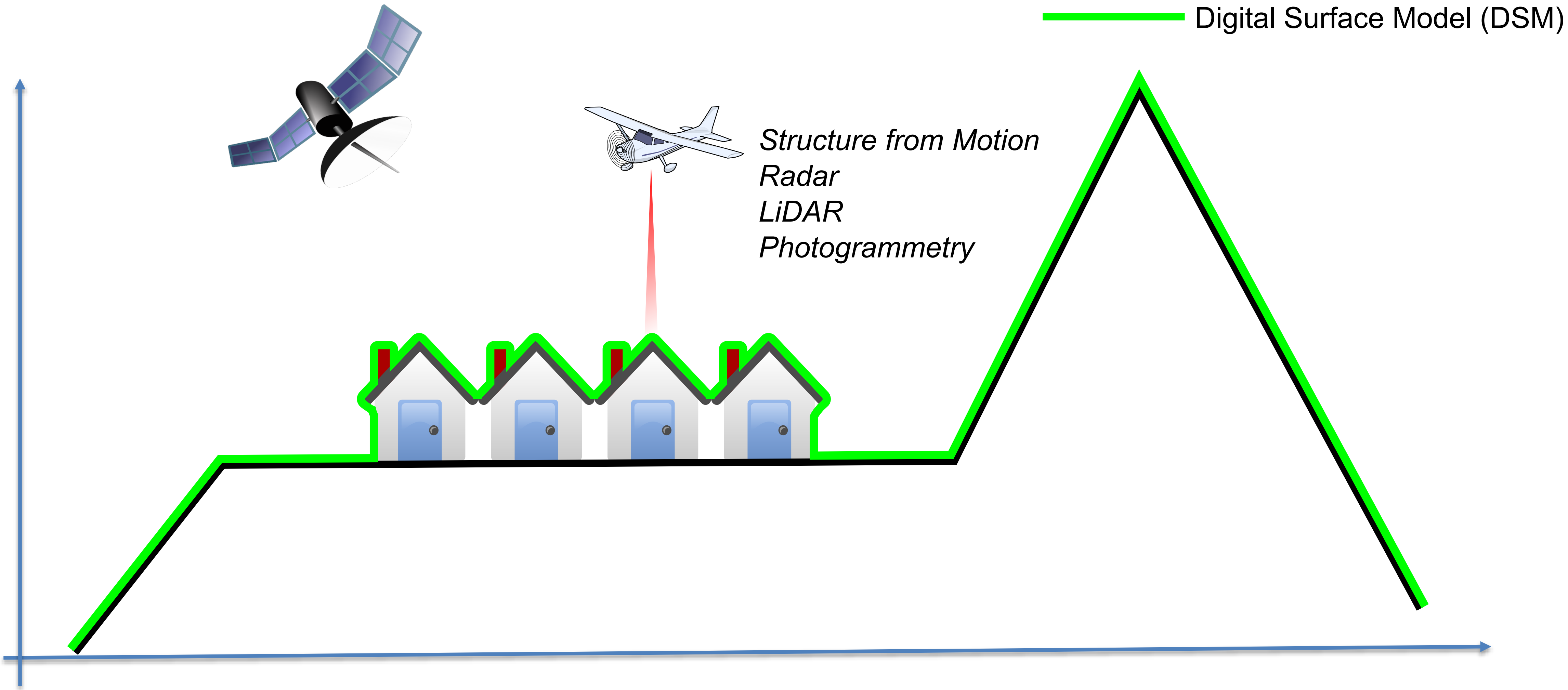
Large-scale DSM Registration via Motion Averaging

Ningli Xu, Rongjun Qin

May 16, 2024

isprs
information from imagery

Digital Surface Model (DSM)



Orthophoto | City Models | Digital Terrain Models | Vectorized Building footprints …

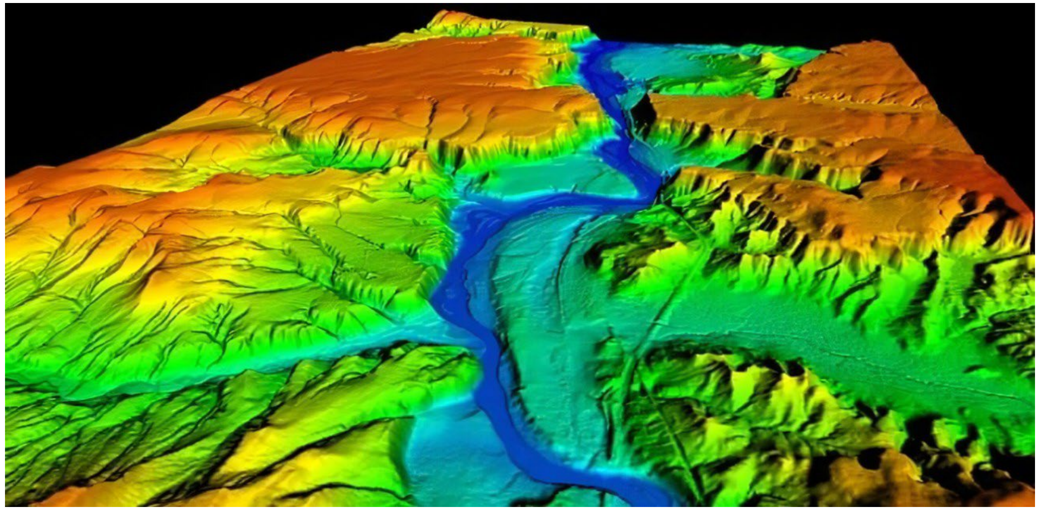
Global-scale mapping

SRTM DEM

ASTER DEM

NASA DEM

ALOS 3D



~ 30 m spatial resolution

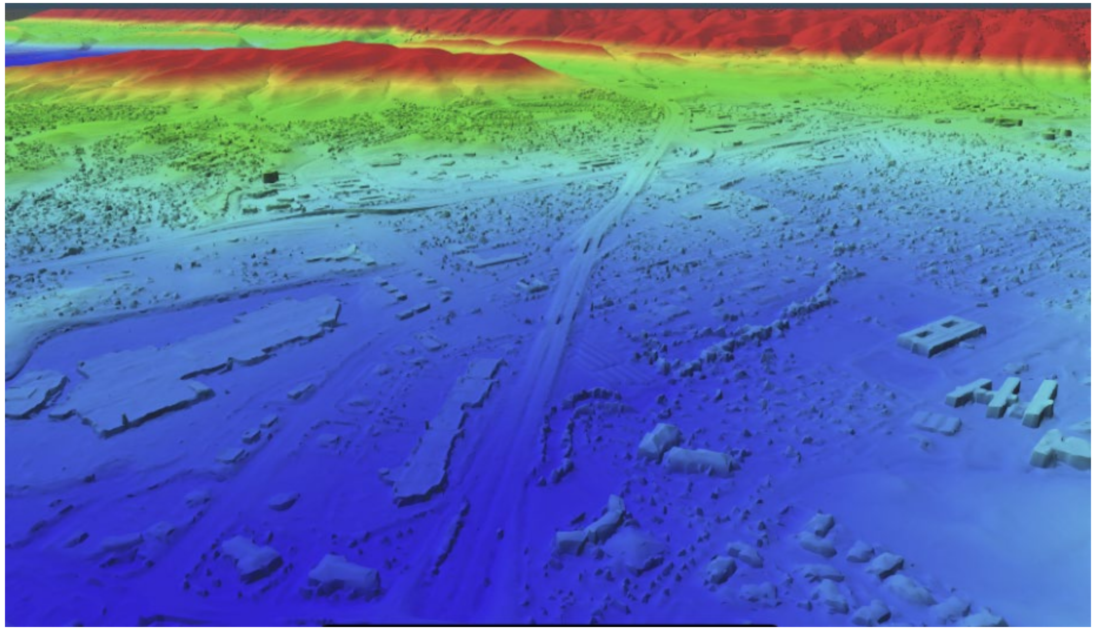
+/- 90 m vertical accuracy

Maxar 3D Foundation

Airbus WorldDEM

ZY-3, GF etc.

....



~ 5-0.5 m spatial resolution

+/- 3-10 m vertical accuracy

Single-source V.S Multi-source

Images → Bundle Adjustment → DSM

V.S.

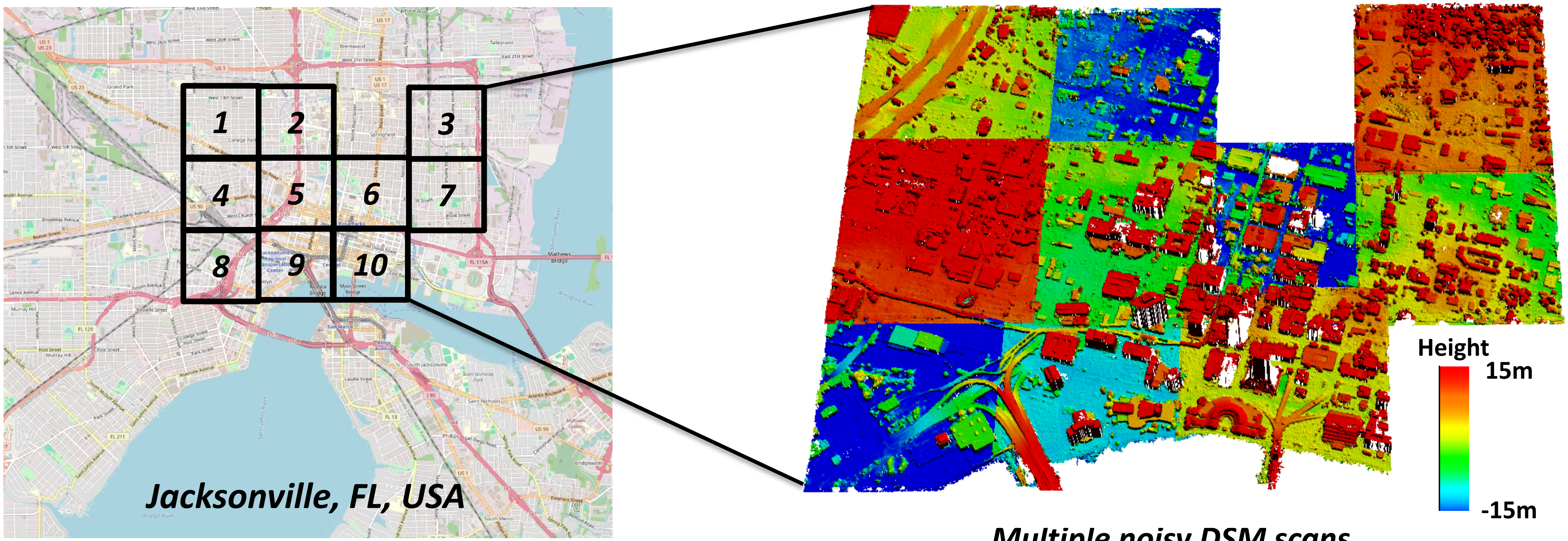
Individual-sourced DSMs → 3D Registration → DSMs

- More sources mean better data availability
- Ability to incorporate sources beyond images
- Potentially more cost-effective.

Problem

Biases exist on individually generated DSMs

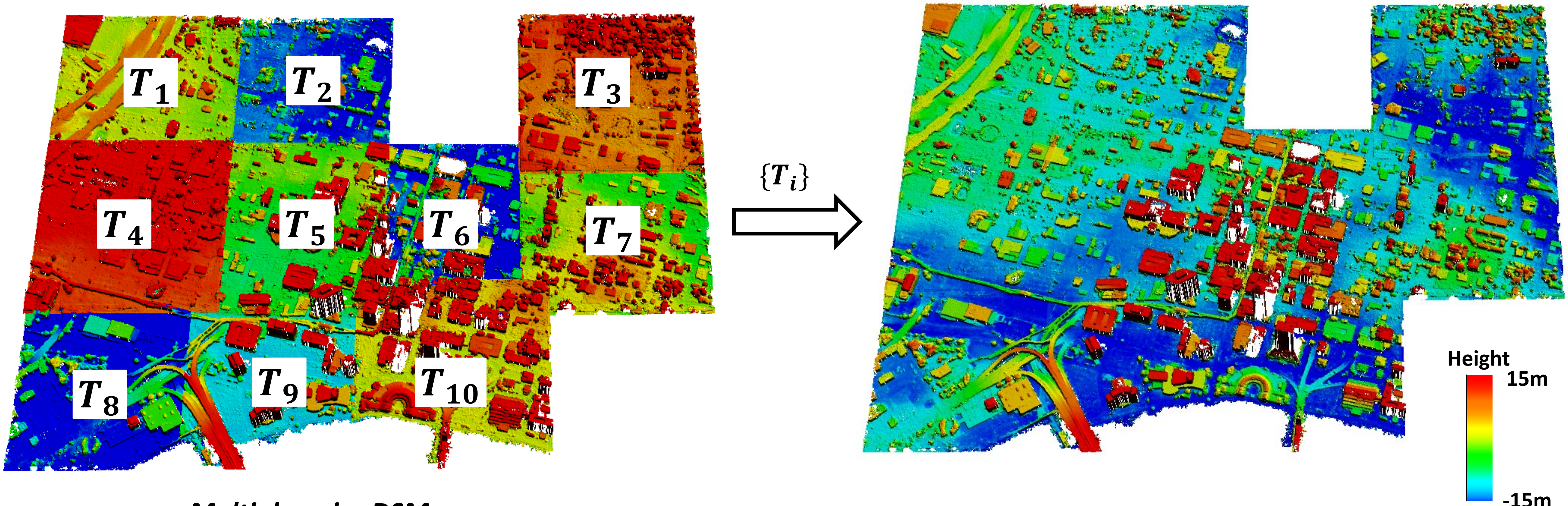
Dataset: *DFC 2019*
Sensor: *26 WorldView2/3 images, LiDAR*
Time span: *Apr,2016 - Aug,2017*



Multiple noisy DSM scans

Core of this work

Estimate the global transformation $\{T_i\}$ to remove the systematic errors of given DSMs



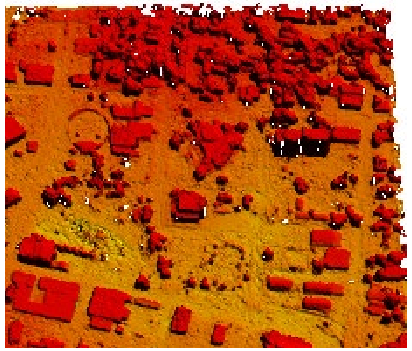
Multiple noisy DSM scans

Multiple registered DSM scans

Challenges

1. Large computation & memory consumption

height: ~10,000 px



#points: ~ 100 million

width: ~10,000 px

2. Some area are flat and featureless

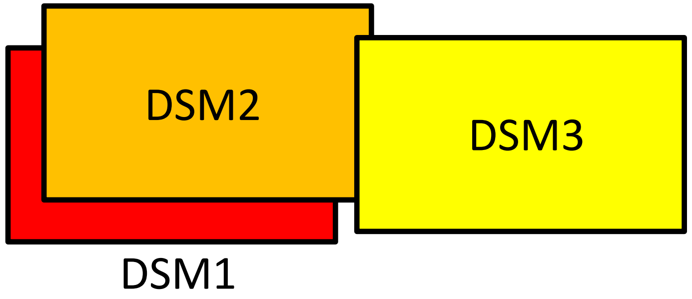
Featureless area leads to ill-posed problem.

Satellite texture

DSM

3. Varying degree of overlaps

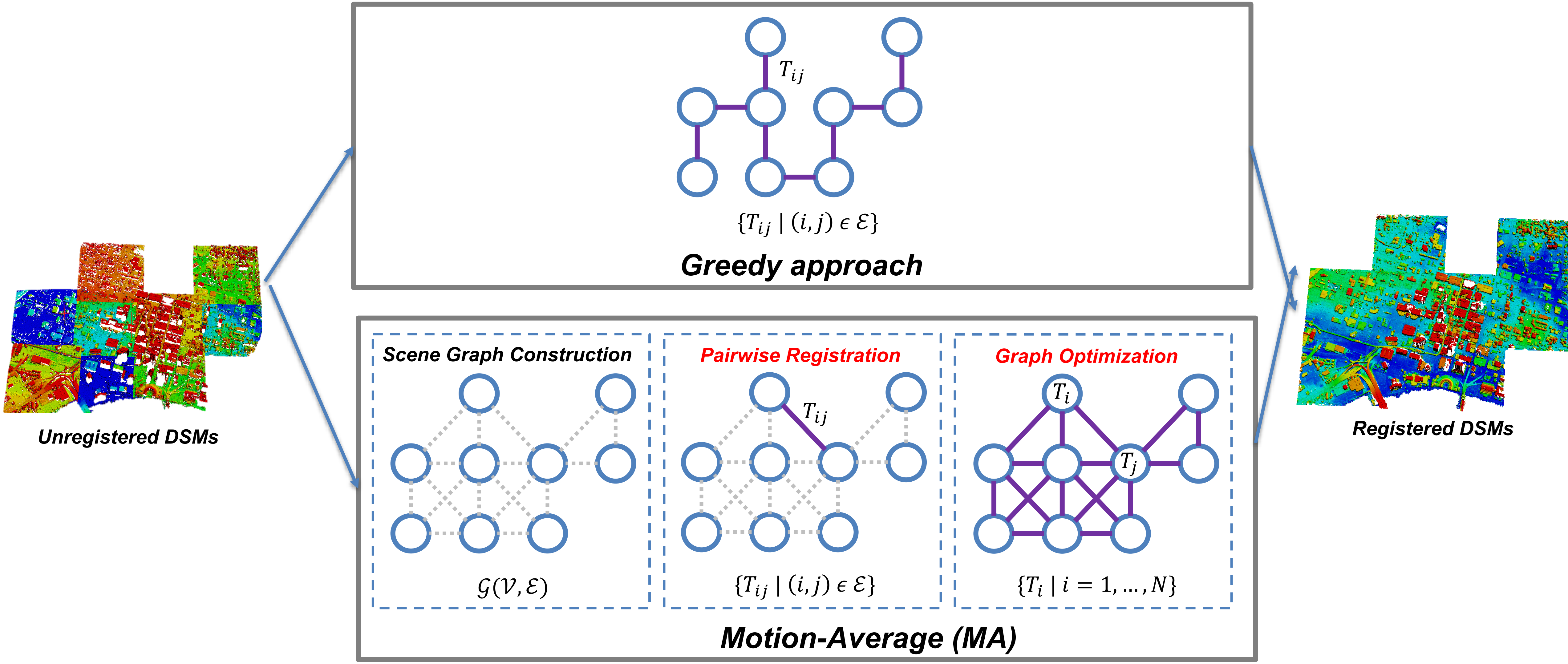
Partial overlapping affects the registration accuracy, which need to be handled respectively



Registration of DSM 1&2 **Easy**

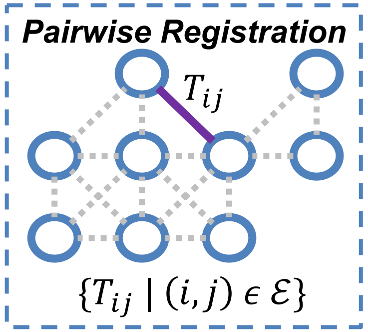
Registration of DSM 2&3 **Hard**

Methodology

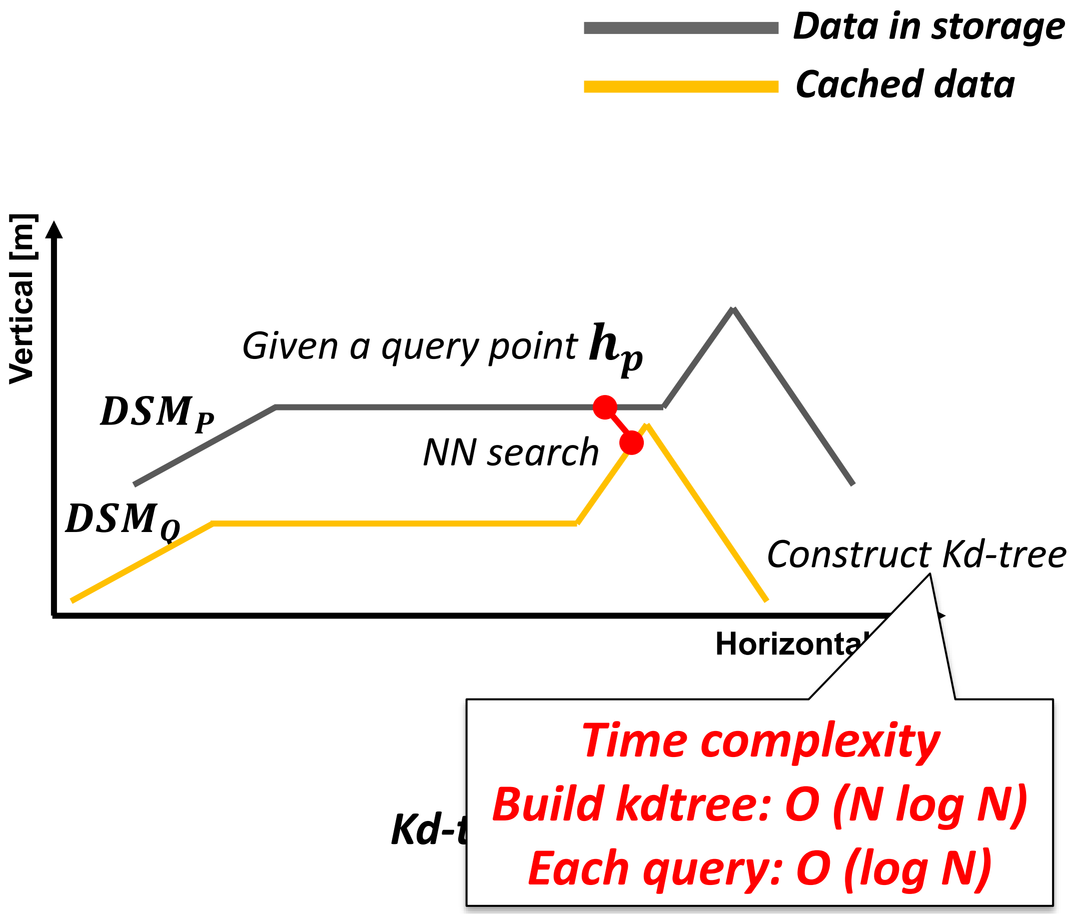


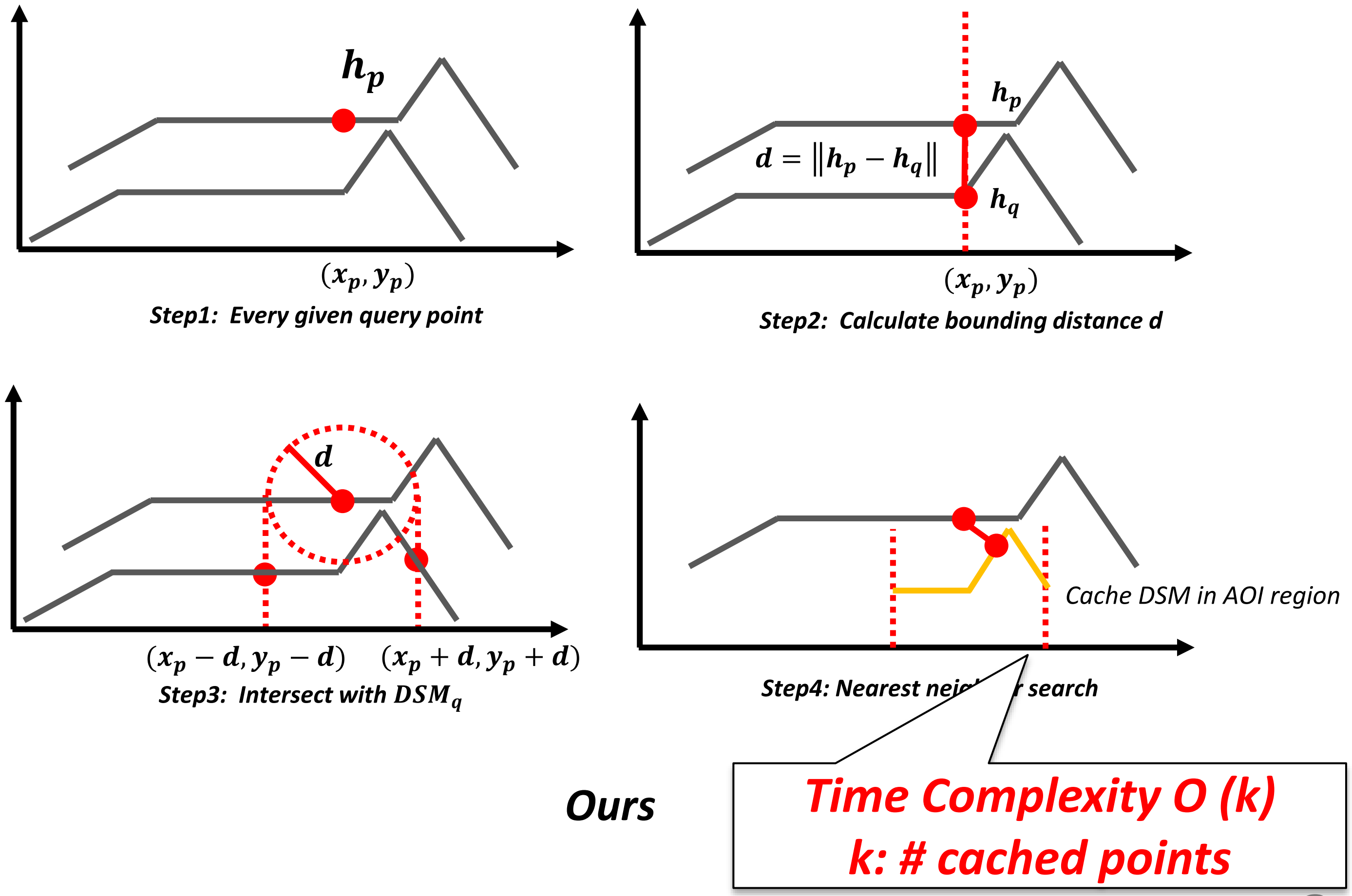
Methodology

1. Pairwise DSM registration : DSM-ICP



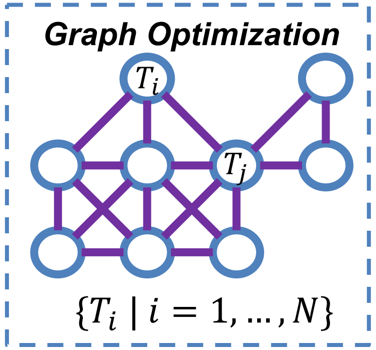
Most resource consuming part is correspondence search. We proposed a fast and exact nearest neighboring search method using the grid structure of DSM.





Methodology

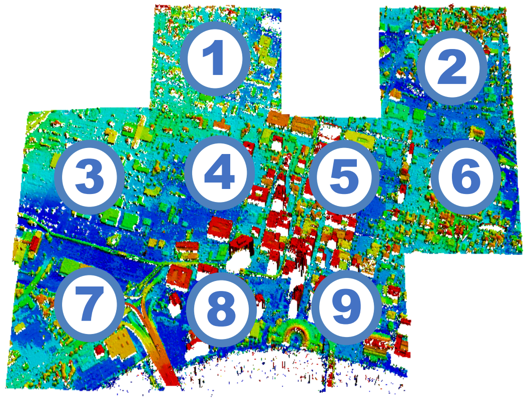
2. Multiview registration: Motion average

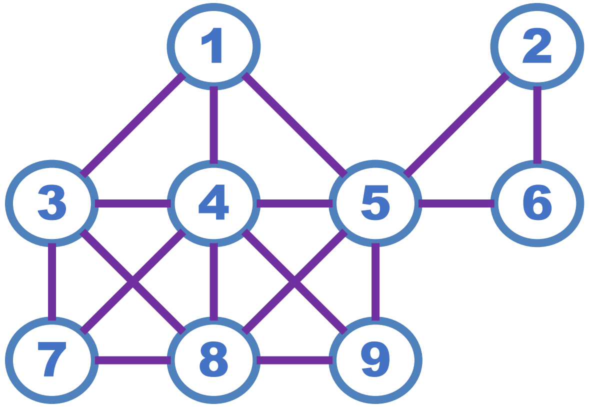


Errors are distributed across the graph

Observation: pairwise transformation $\{T_{ij}\}$

Optimizable variable: global transformation $\{T_i\}$





$$\min_{\{T_i\}} \sum \mathrm{w}_{ij} \left\| T_{ij} - {T_i}^{-1} \cdot T_j \right\|_F^2$$

$$\mathrm{w}_{ij} = s_{ij} * r_{ij}$$

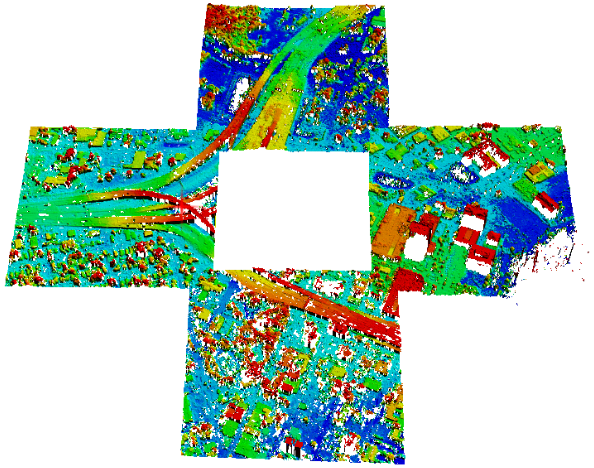
Overlap ratio *Pairwise registration quality*

$$\boldsymbol{r_{ij}} = \frac{e^{-err_{ij}}}{\sum_{(i,j)} e^{-err_{ij}}}$$, $\boldsymbol{err_{ij}}$ **is pairwise registration error**

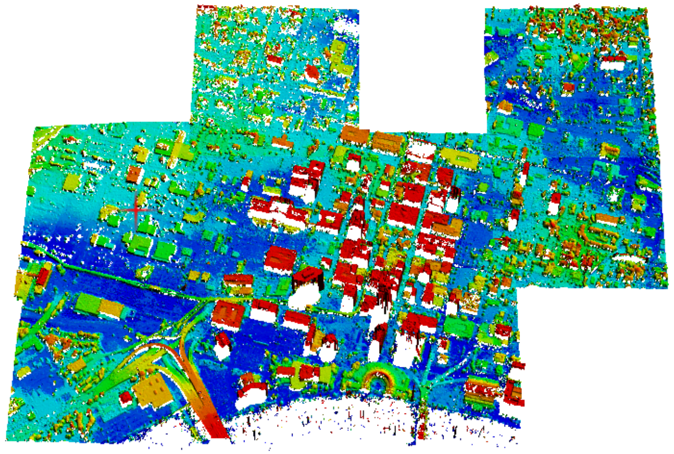
Ours

Experiment

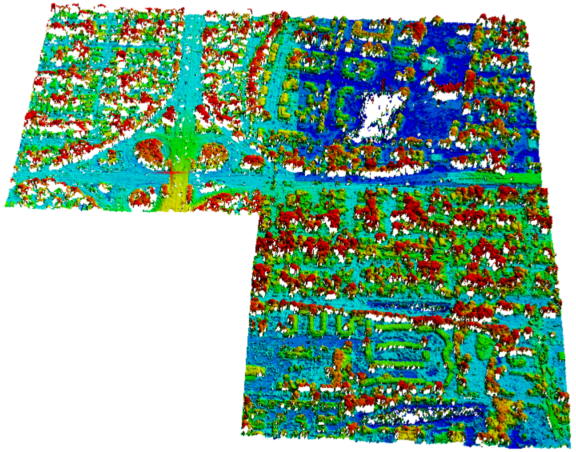
Dataset: *DFC 2019 [1]*
Ground truth: *airborne LiDAR*
Metric: *RMSE*



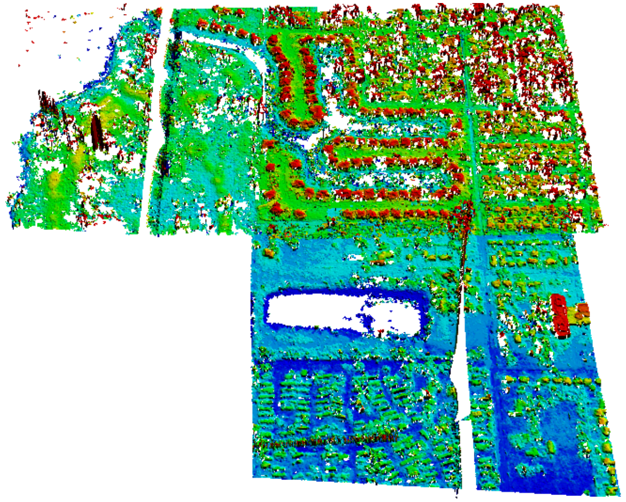
Jacksonville Area1 (4 DSMs, 4.5 KM^2)



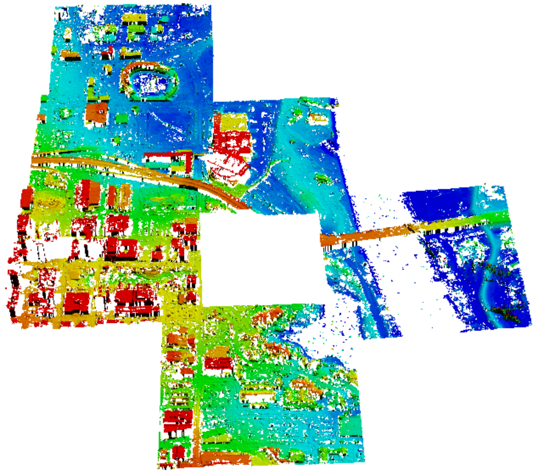
Jacksonville Area2 (9 DSMs, , 6 KM^2)



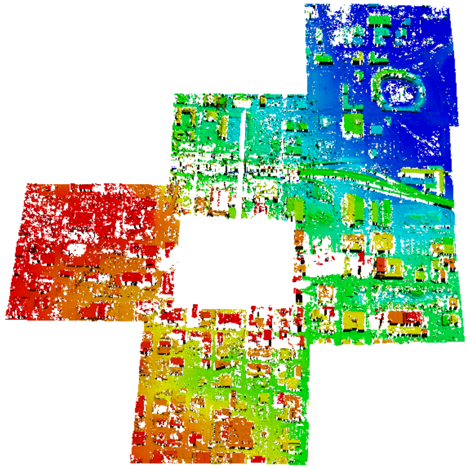
Jacksonville Area3 (3 DSMs, 2 KM^2)



Omaha Area1 (3 DSMs , 2 KM^2)



Omaha Area2 (6 DSMs , 6 KM^2)



Omaha Area3 (6 DSMs , 6 KM^2)

[1] https://ieee-dataport.org/open-access/data-fusion-contest-2019-dfc2019

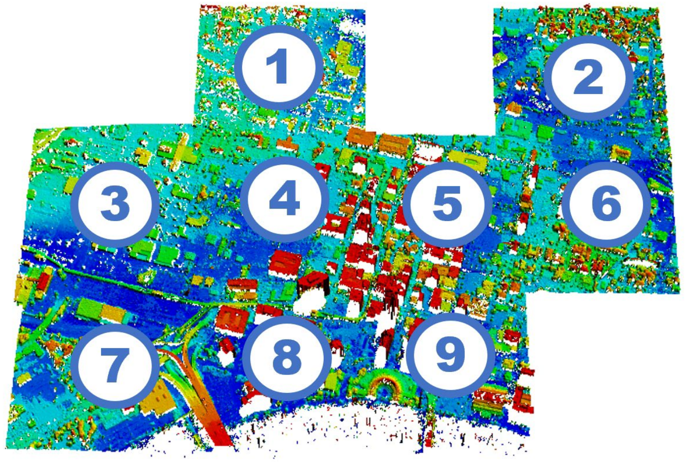
Experiment

Accuracy of multiple registration

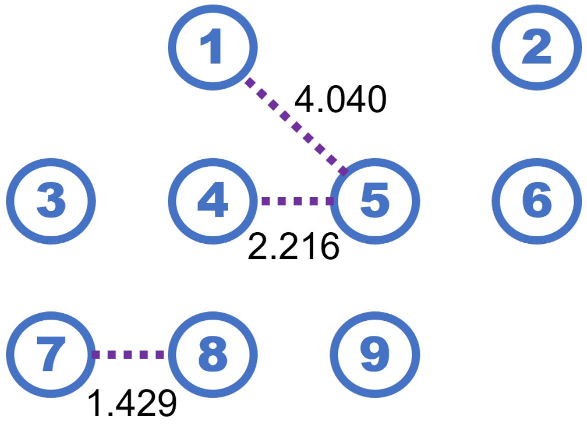
Method	RMSE [m]					
	JAX1	JAX2	JAX3	OMA1	OMA2	OMA3
Greedy	2.305	2.166	2.756	2.065	1.461	1.667
M-A	2.302	2.129	2.756	2.065	1.451	1.539

Experiment

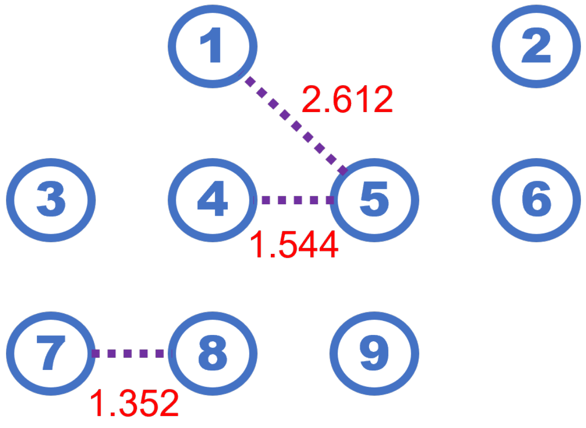
Accuracy of multiple registration



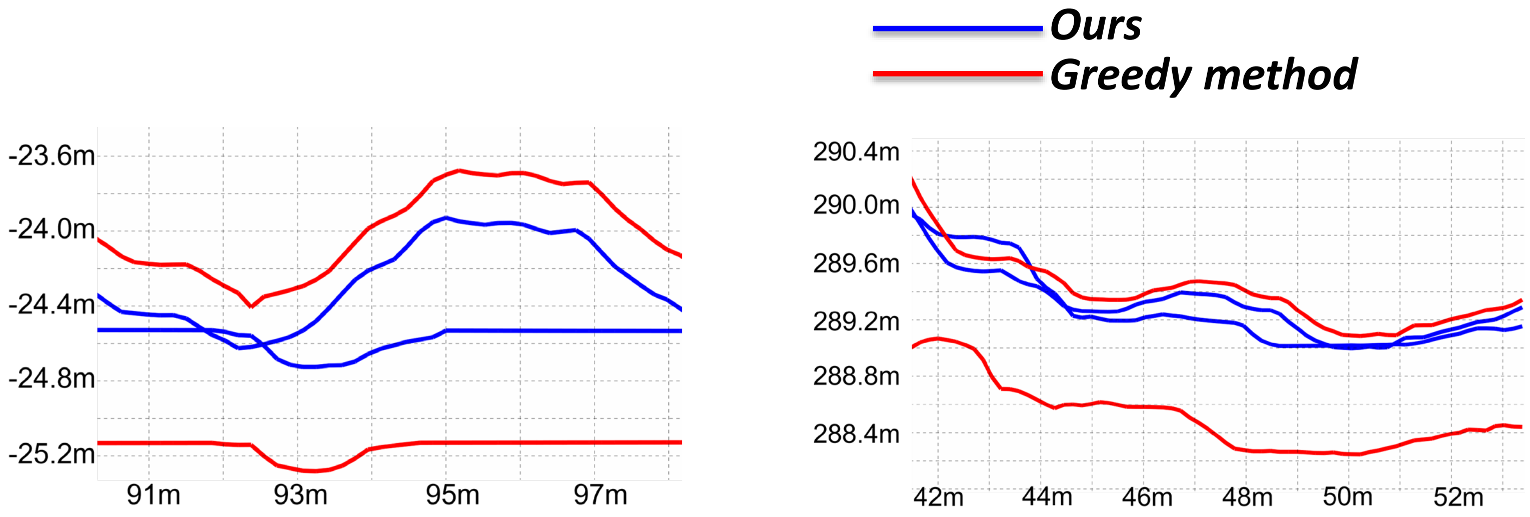
Jacksonville Area2



Pairwise accuracy (RMSE [m]) of greedy's results



Our result

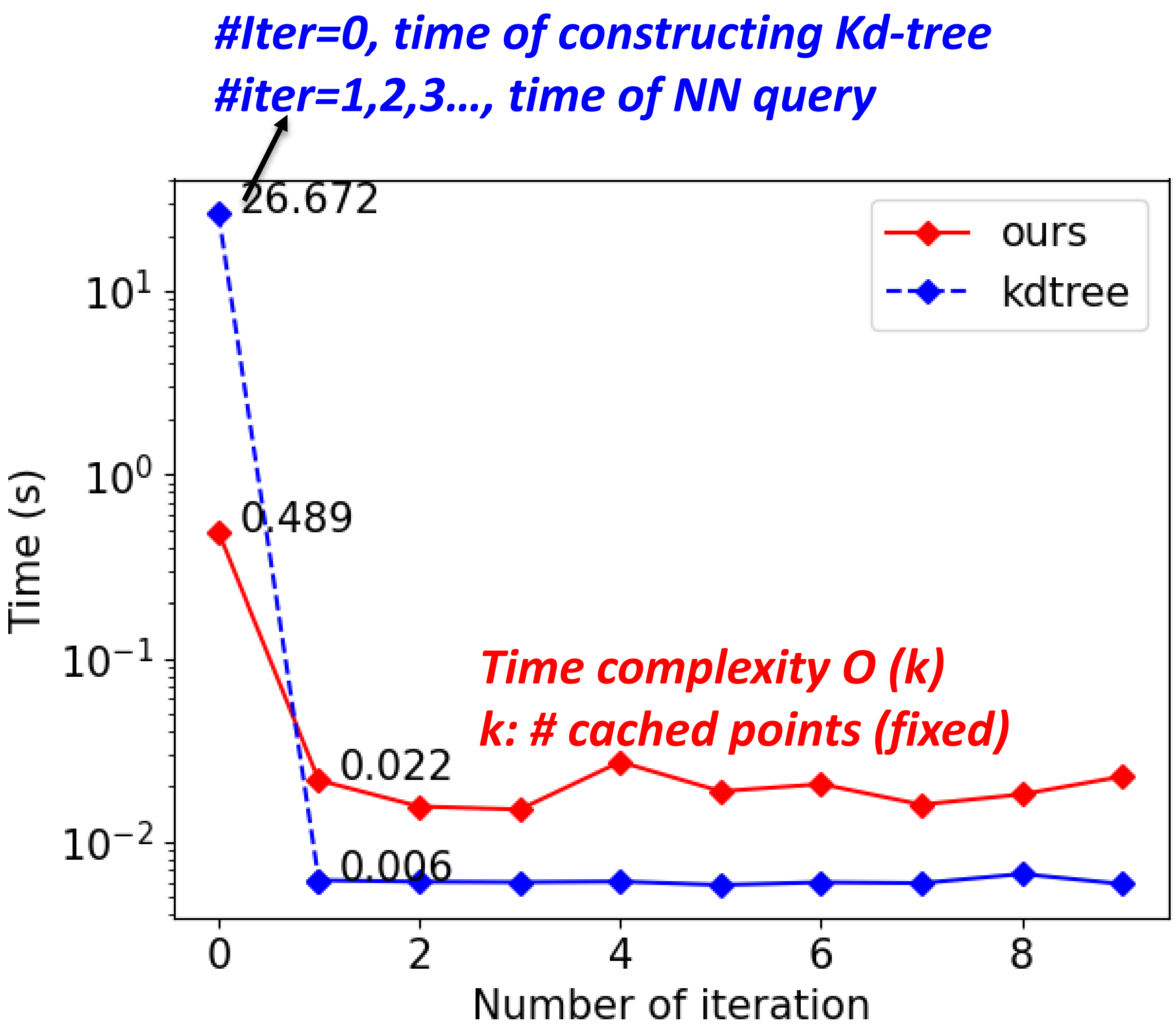


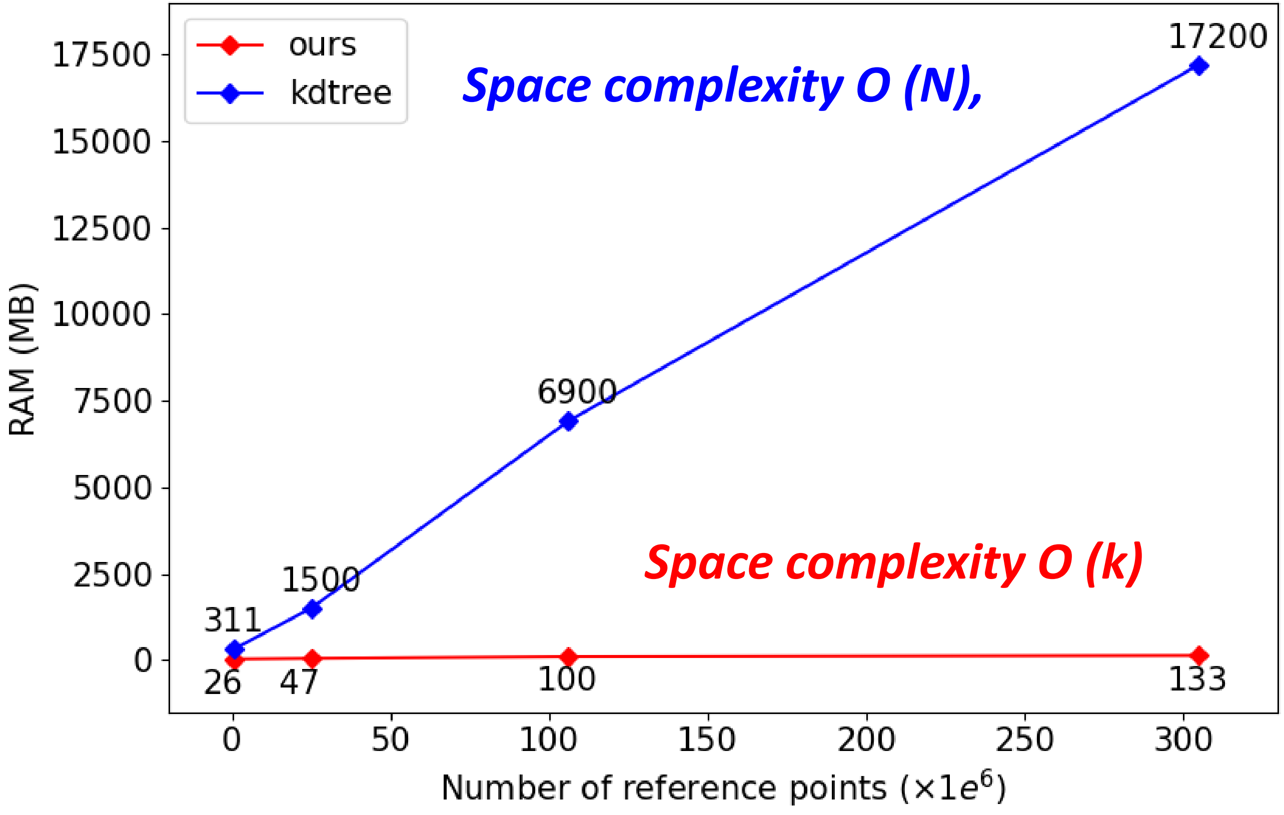
Profile in Jacksonville area2

Experiment

Time consumption of pairwise registration

Memory consumption of pairwise registration





106 million points

Experiment

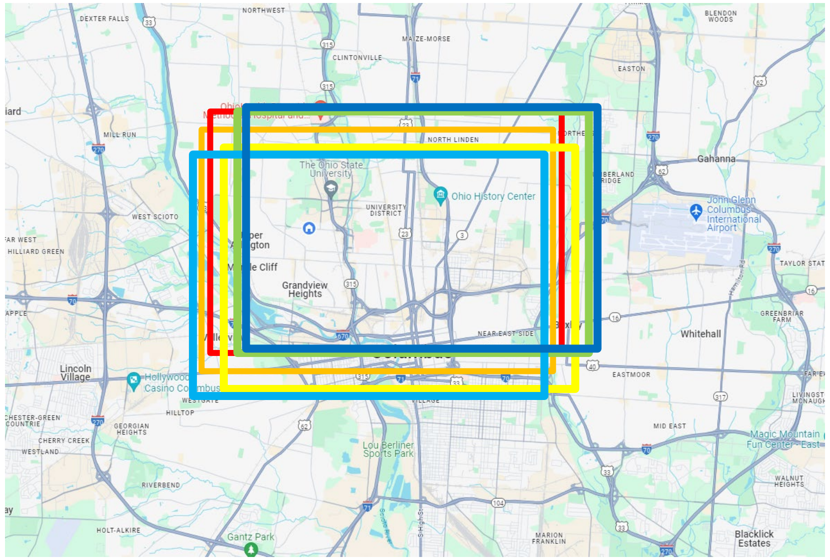
Wide area DSM (132 individual DSMs)

Santa Cruz, Argentina, $\boldsymbol{4974\ KM^2}$

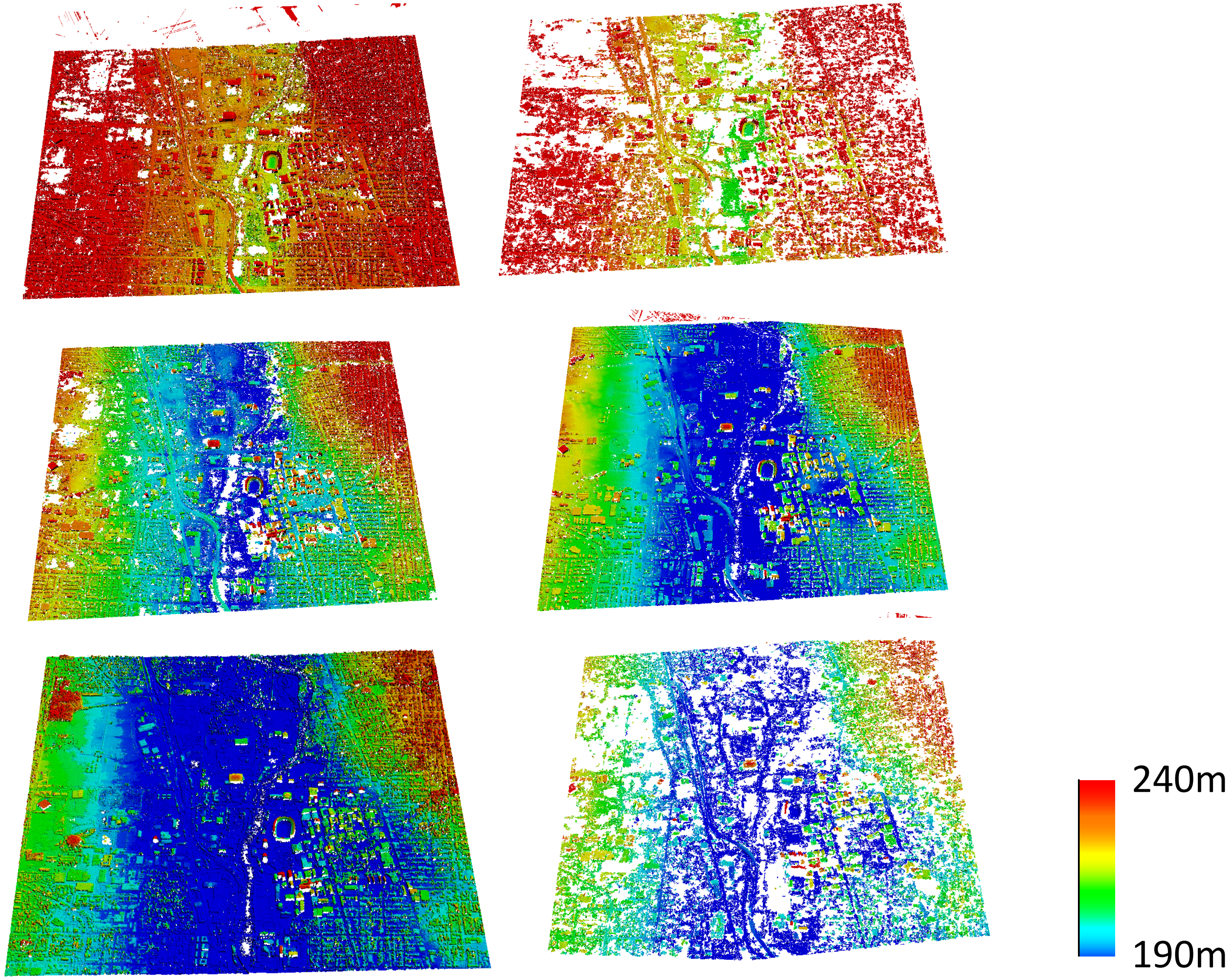
QinLab
Geospatial Data Analytics

Experiment

Wide area DSM (66 individual DSMs, including LiDAR DSM and Drone DSMs)

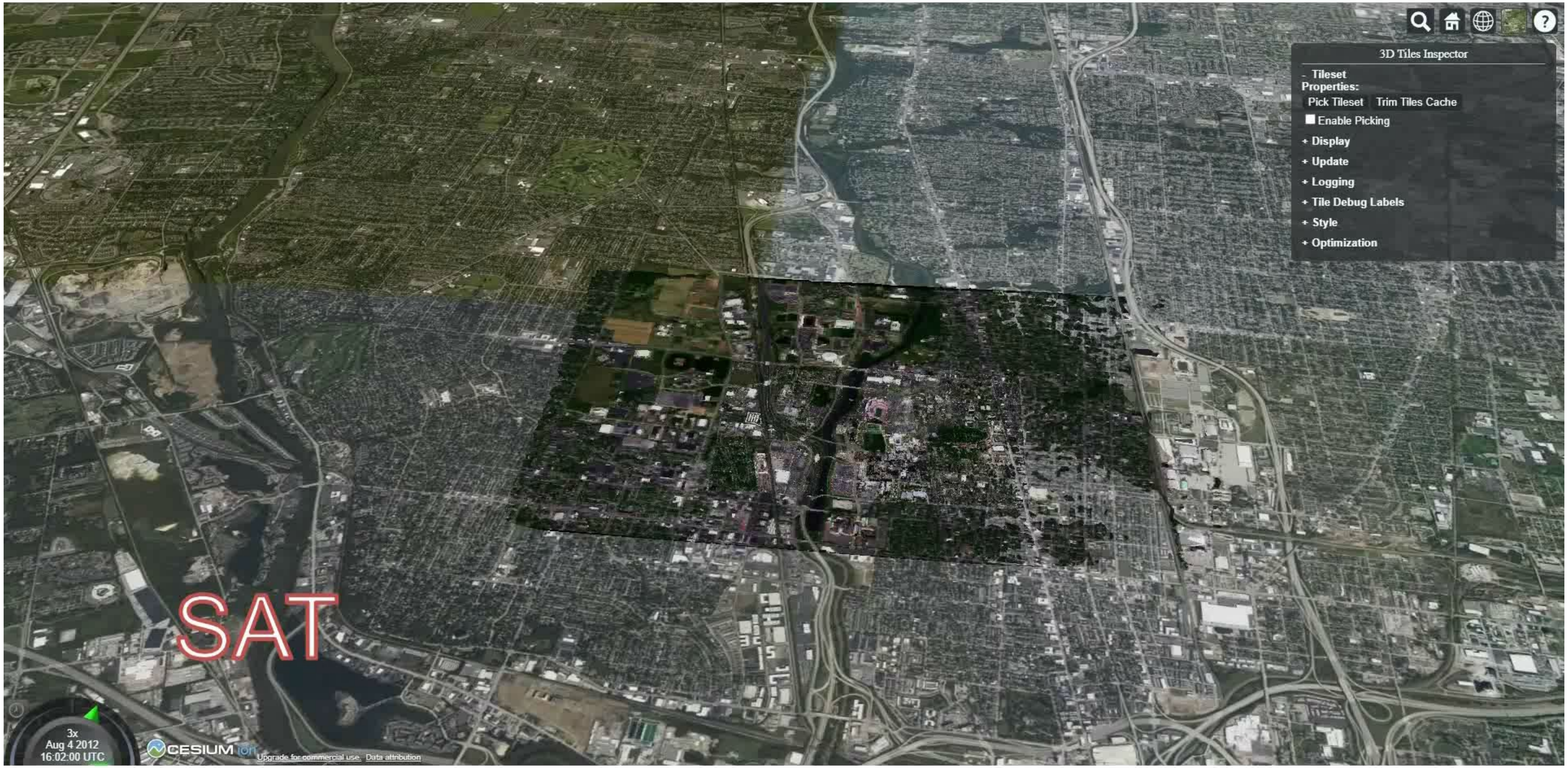


15 KM^2
Columbus, OH, USA



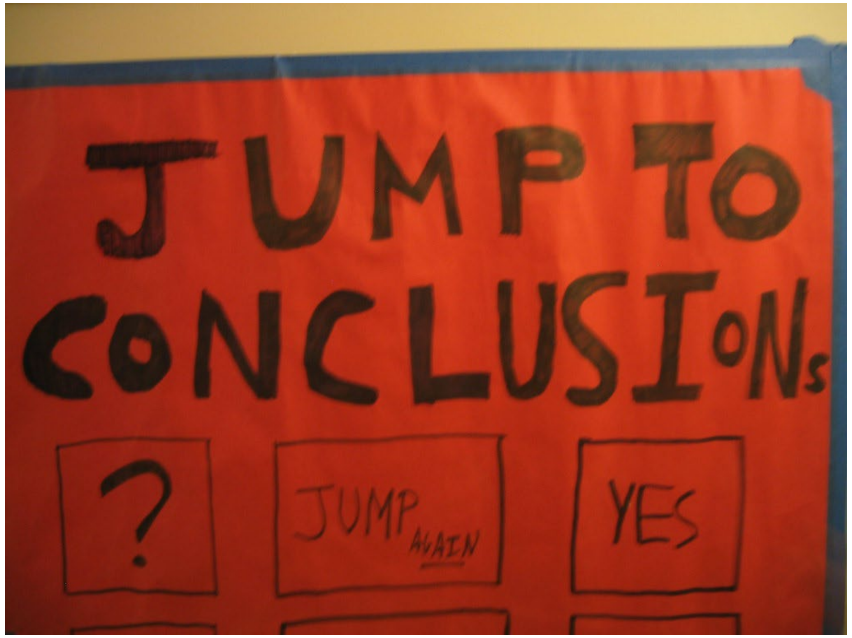
Experiment

Multi-source DSM



Columbus, OH, USA

Conclusions



- The use of the grid-structure is in good favor of large-scale DSM registration
- The motion average method is extremely effective in reducing systematic biases over multiple DSMs.