Urban Semantic 3D Reconstruction from Multiview Satellite Imagery

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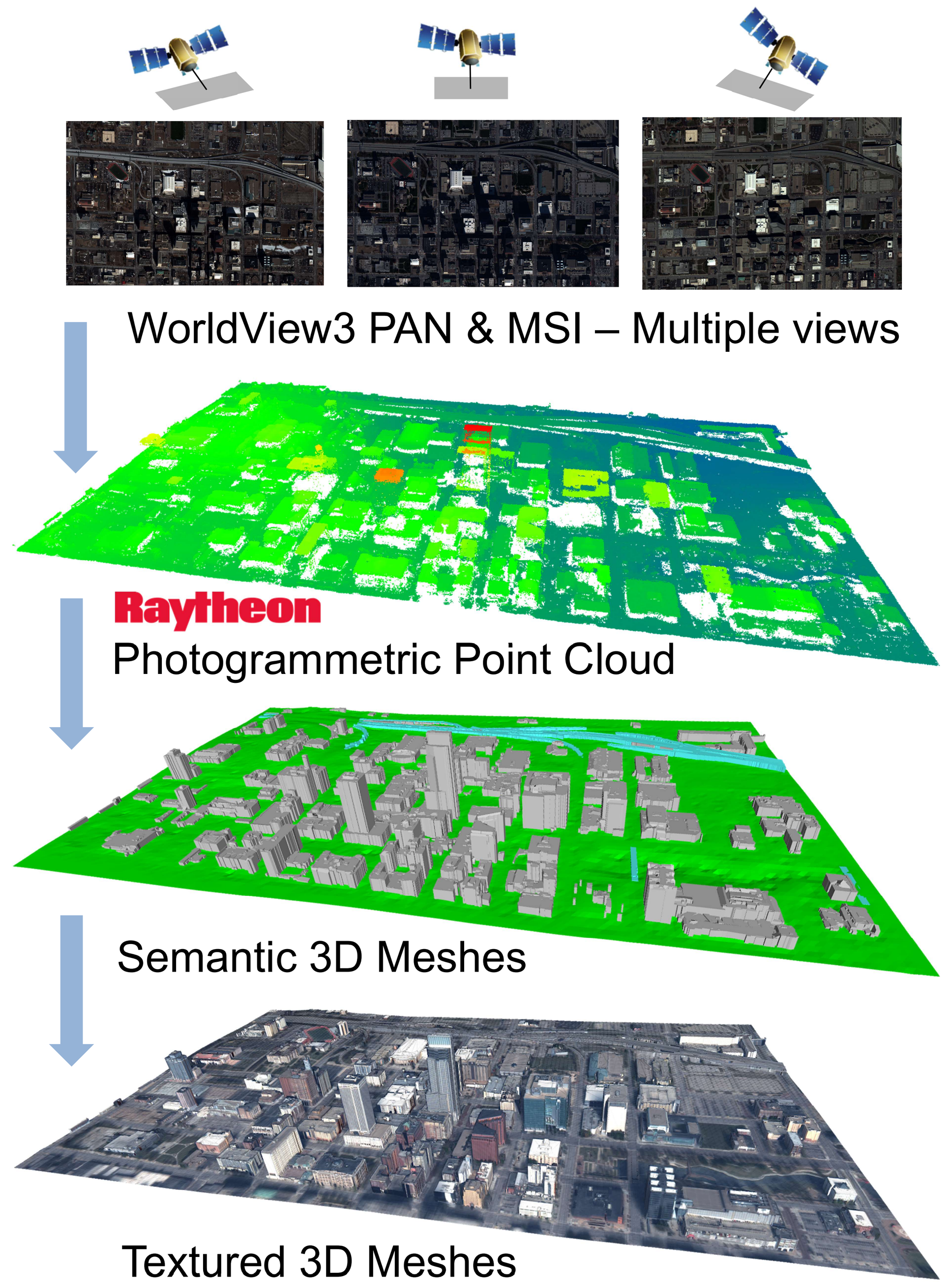
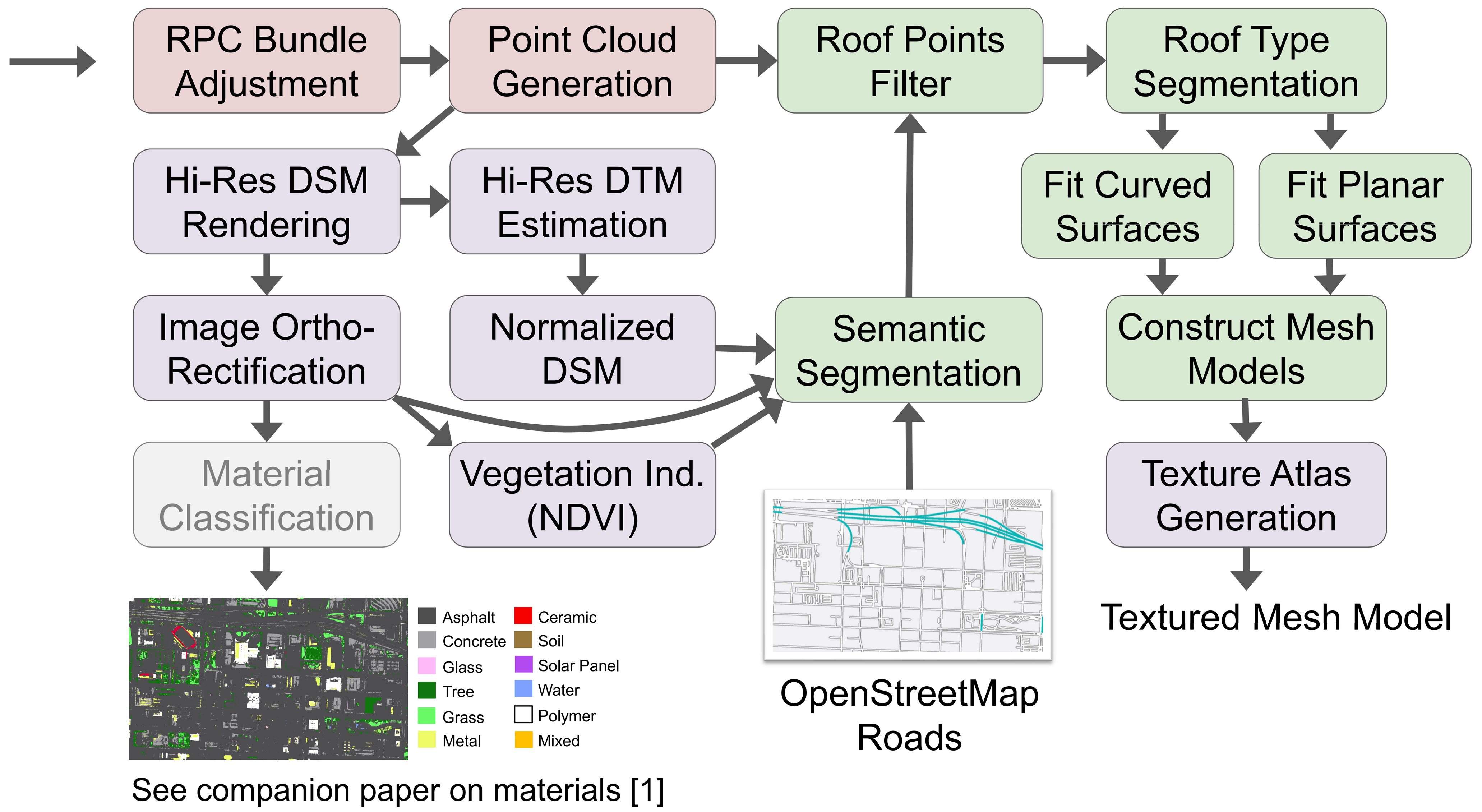
Overview

Automatic, simple 3D mesh models from satellite images

- Build on existing commercial point cloud generation software (Raytheon Intersect Dimension)
- Segment scene into buildings, bridges, and terrain
- Model buildings/bridges with geometric primitives
  - Regularized planar roof sections
  - Cylindrical and spherical roofs
- Texture map using multiple satellite images
- Deploy on AWS with web-based application for easy use
- Release open source software





Results

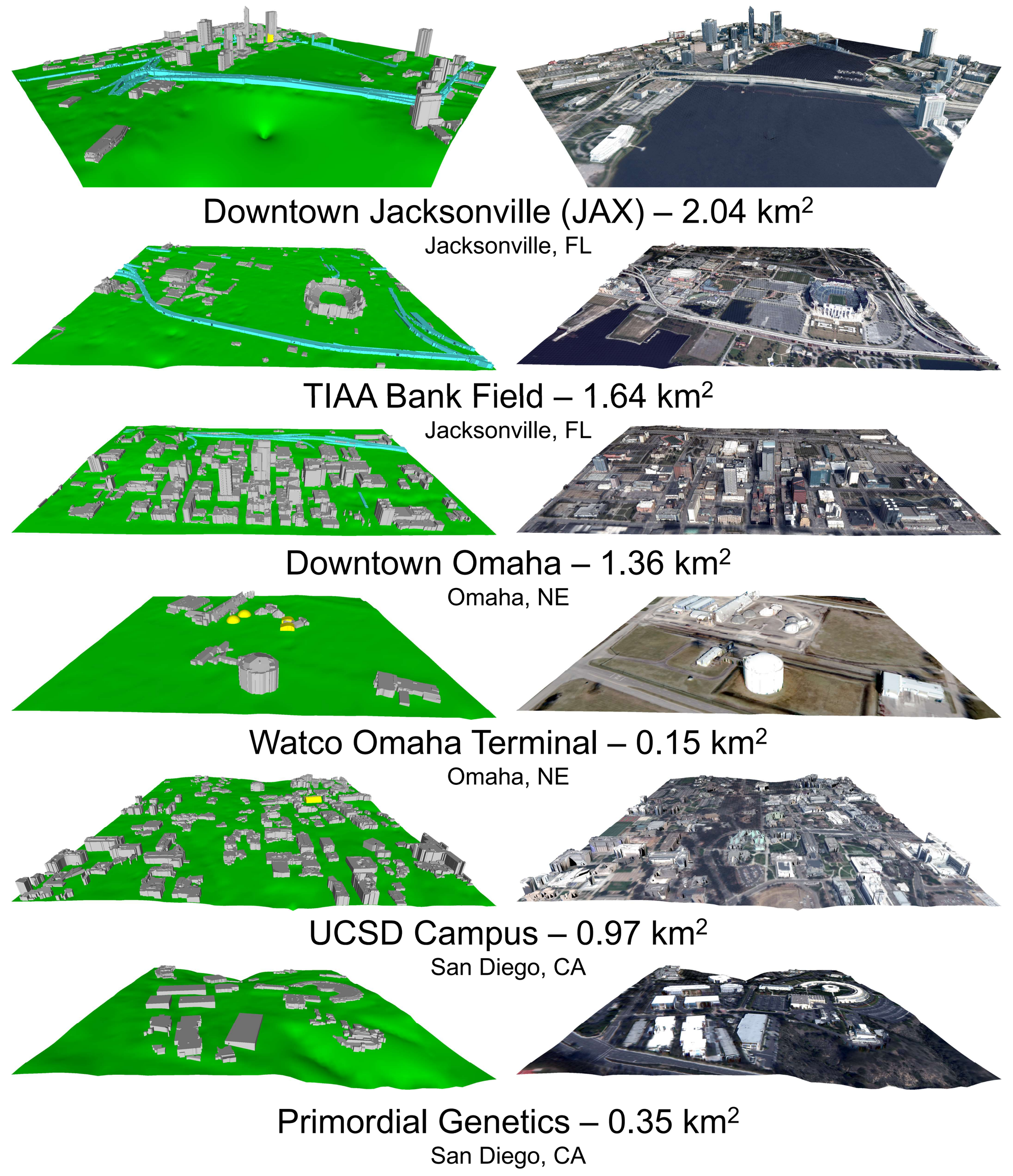
- Evaluated on the CORE3D public data and metrics
- Ground truth on 2 AOIs (UCSD and JAX)

Building Segmentation

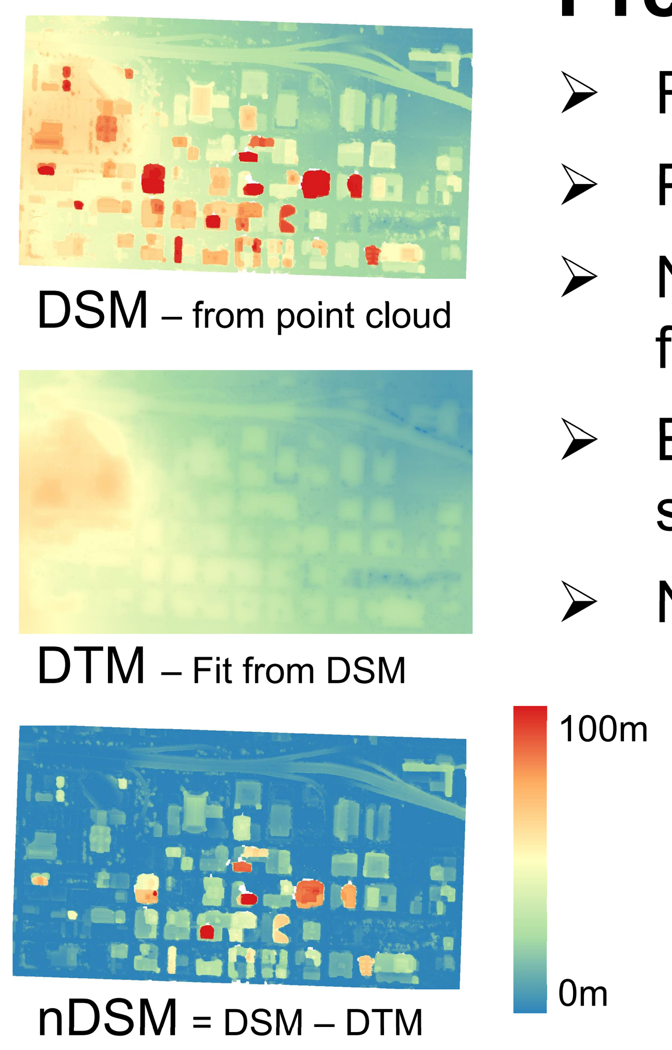
Method	UCSD P	UCSD R	UCSD IoU	JAX P	JAX R	JAX IoU
Threshold	0.69	**0.90**	0.64	**0.83**	0.83	**0.71**
GoogLeNet	0.84	0.89	**0.75**	0.79	0.80	0.66
DenseUNet	**0.87**	0.85	**0.75**	0.63	0.86	0.57
PSPNet	0.82	**0.90**	**0.75**	0.76	**0.87**	0.69

Overall Performance

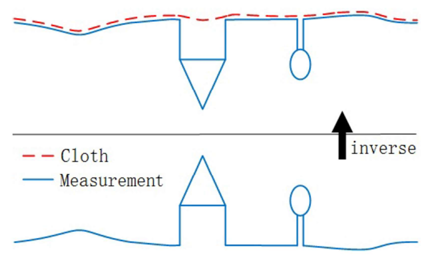
CORE3D Metric	UCSD	JAX
2D Correctness	0.91	0.90
2D Completeness	0.75	0.71
3D Correctness	0.88	0.91
3D Completeness	0.75	0.75
Geolocation Error (m)	1.58	2.24
Z-RMSE (m)	1.29	0.60
H-RMSE (m)	1.80	2.06
Run Time (hr / km^2)	4.80	2.28



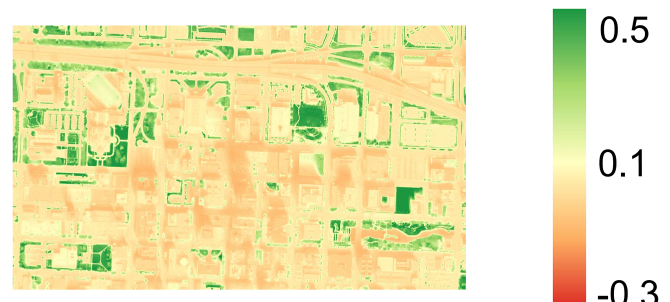
Preprocessing



- Render a Digital Surface Model (DSM)
- Pansharpen and orthorectify images to DSM
- Normalized Difference Vegetation Index (NDVI) from ortho images to help remove trees
- Estimate Digital Terrain Model (DTM) with cloth simulation filter (Zhang et al. [2])
- Normalized DSM (nDSM) to factor out terrain



Zhang et al. [2] inverted cloth draping



NDVI = (NIR-Red) / (NIR+Red)

Semantics & Shape Fitting

- Semantic segmentation from MSI, nDSM, & NDVI inputs
  - Two-class (building / background) first, use OSM roads to separate building / bridge
  - Simple thresholding (NDVI > 0.1 and nDSM > 2m) + morphology as a baseline
  - Compared three deep networks (GoogLeNet [7], DenseUNet [5]+[6], PSPNet [8])
- Use segmentation to filter building/bridge points from point cloud
- Classify points as flat, sloped, cylindrical, or spherical with PointNet++ [4]
  - Augment limited curved training samples by "bending" planar samples
- Fit roof segments per shape category
  - Hierarchical roof topology tree [4] applied to planar segments

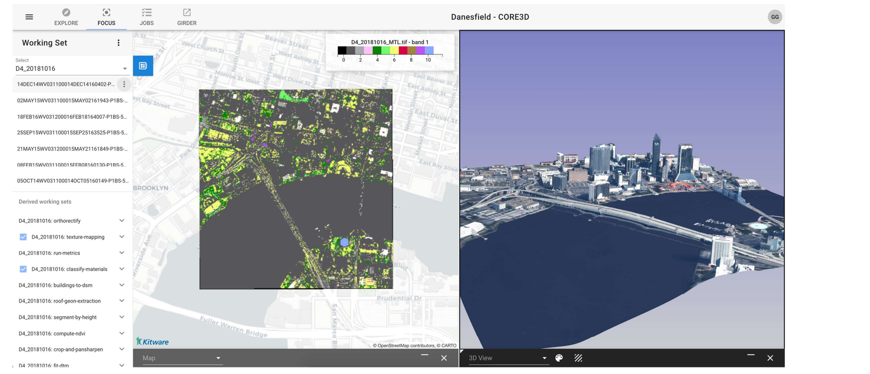
Threshold Segmentation

Software

- Software named **Danesfield** in honor of the WWII center for 3D aerial photographic intelligence
- Algorithms in Python with some C++
  - Environment configured with Conda or Docker
- Web Application
  - 3D model and map-based visualization
  - Data and job management
  - Deployed on Amazon Web Services
- **Open source**: Apache License Ver 2.0

Raytheon point cloud estimation code is not open source but binaries are available to the US Government with Government Purpose Rights.

Danesfield House, 1945
Medmenham, England



Danesfield Web Application

https://github.com/Kitware/Danesfield-App

Acknowledgements

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Key References

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[8] Zhao et al. *Pyramid Scene Parsing Network*. CVPR 2017.