Automatic 3D Reconstruction from Multi-Date Satellite Images

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Objective

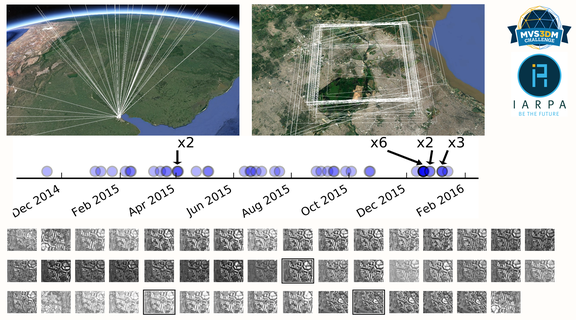
Compute a 3D model from many satellite images of the **same site** at **different dates**.

Contributions

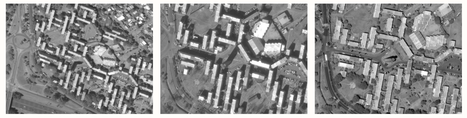
- 3D models obtained by fusing few **well-chosen multi-date pairs** can be as accurate as those obtained from a same-date pair
- Heuristic pair selection criterion
- A fusion strategy that accounts for seasonal vegetation changes

IARPA MVS challenge* dataset

47 images of Buenos Aires acquired over 14 months [1]



Variable image quality



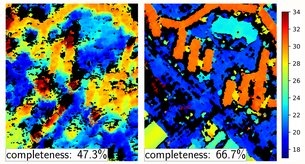
incidence angle noise & reflections seasons

* An early implementation of the proposed method was used to win the *IARPA Multi-View Stereo 3D Mapping Challenge 2016*.

Algorithm

The quality of 3D models from multi-date pairs varies wildly!

We aggregate models computed from **well-chosen pairs.**

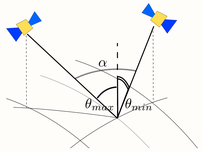


same-date (θ_{max}: 45°) multi-date (θ_{max}: 15°)

1. *Image Pair Selection*

Proposed pair selection heuristic:

- Maximum incidence angle $\theta_{max} < 40°$
- Angle between the views $\alpha \in [5, 45]°$
- Temporal proximity

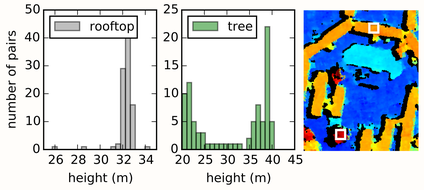


2. *Stereo Matching of Selected Pairs*

- Use a modular *Satellite Stereo Pipeline*: S2P [2]
- Census-based correlator MGM [3] + ad-hoc mismatch filtering
- Triangulation without pointing correction

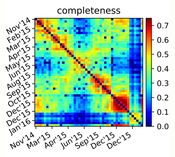
3. *Alignment and Fusion*

- **Align** DSMs by correlation (bias correction [4])
- **Merging.** Instead of median [5], take the **lower cluster** of the height histogram (removes seasonal vegetation)

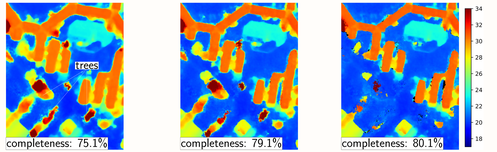


Justifications

Heuristic order is obtained by studying the **oracle order.** Use training data to compute and evaluate all 2162 image pairs. Sort pairs with **decreasing completeness** (% of pixels with error below 1 m).

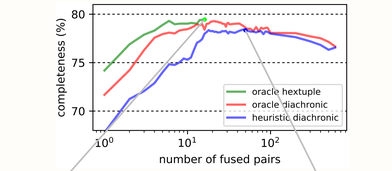


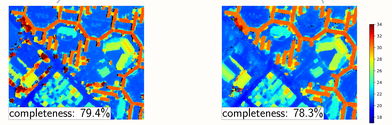
Different fusions of best N pairs according to heuristic order



median of 700 pairs [5] median of 50 pairs k-medians of 50 pairs

Can a model obtained exclusively from multi-date images be as accurate as one from a single same-date stereo pair?





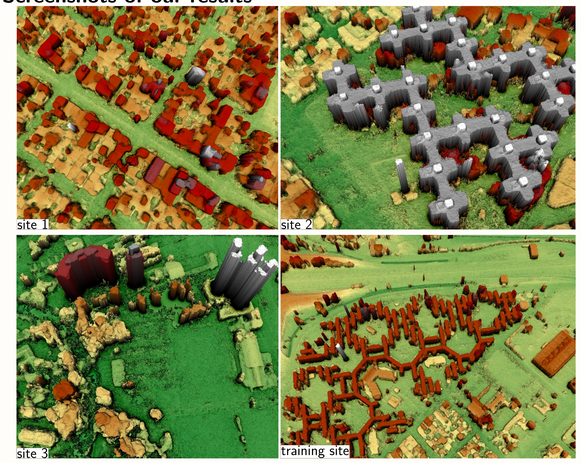
same-date hextuple (15 pairs) 38 multi-date images (50 pairs)

Completeness & RMSE of merged DSMs using 50 pairs

site	heuristic order med	heuristic order k-med	oracle order med	oracle order k-med
training	79.0 / **2.67**	**80.1** / 2.89	79.3 / **2.69**	**80.2** / 2.89
site 1	73.6 / **1.80**	**74.0** / 1.88	74.4 / **1.79**	**74.7** / 1.88
site 2	71.8 / 3.97	**73.1** / **3.87**	71.6 / 3.85	**73.1** / **3.79**
site 3	57.2 / **6.73**	**58.6** / 7.52	57.9 / **6.36**	**59.6** / 6.98

Results

Screenshots of our results



IARPA challenge scoreboards

solution	site 1 comp	med	RMS	site 2 comp	med	RMS	site 3 comp	med	RMS	score
Psyho	60%	0.24	1.29	55%	0.19	1.75	43%	**0.14**	3.24	**92.5%**
carlito	69%	**0.17**	**1.28**	61%	**0.16**	2.35	45%	0.26	3.69	90.2%
sdrdis	52%	0.48	1.48	51%	0.27	**1.69**	38%	0.32	**3.21**	87.7%
kbatsos	67%	0.34	2.06	56%	0.33	3.31	44%	0.73	5.06	75.4%
jacobgal.	69%	0.49	2.04	**63%**	0.67	4.11	**53%**	1.01	6.65	74.1%
qinrj321	68%	0.47	1.78	60%	0.68	3.82	46%	1.15	6.60	72.8%
JHU/APL	**70%**	0.39	1.90	59%	0.59	3.96	43%	1.34	9.95	-

Provisional scores (3 known sites)

solution	score
carlito	**96.3%**
Psyho	93.6%
sdrdis	79.9%
qinrj321	76.0%
kbatsos	67.2%

Final scores (4 unknown sites)

site	comp	med	RMS
1	69%	0.20	1.17
2	64%	0.19	1.43
3	55%	0.22	2.46
4	64%	0.19	2.16

Carlito detail

References

[1] Bosch Ruiz et al. A Multiple View Stereo Benchmark for Satellite Imagery. *IEEE AIPR Workshop*, 2016.

[2] de Franchis et al. An automatic and modular stereo pipeline for pushbroom images. *ISPRS Annals*, 2014.

[3] Facciolo et al. MGM: A Significantly More Global Matching for Stereovision. *BMVC*, 2015.

[4] Grodecki and Dial. Block adjustment of high-resolution satellite images described by Rational Polynomials. *Photogramm Eng. Remote Sensing*, 2003.

[5] Ozcanli et al. A comparison of stereo and multiview 3-D reconstruction using cross-sensor satellite imagery. *2015 IEEE CVPR Workshop*, 2015.