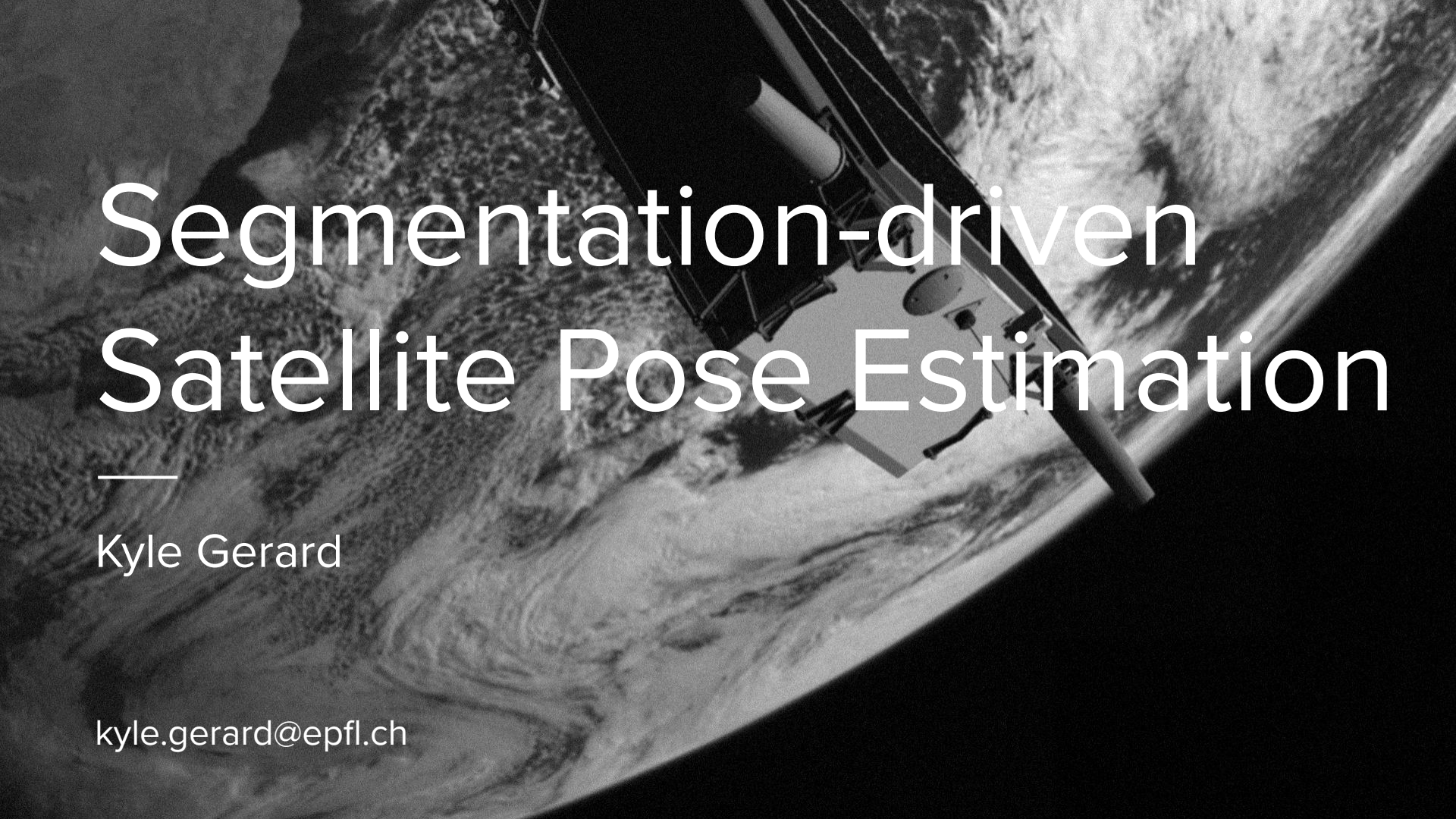

Segmentation-driven Satellite Pose Estimation

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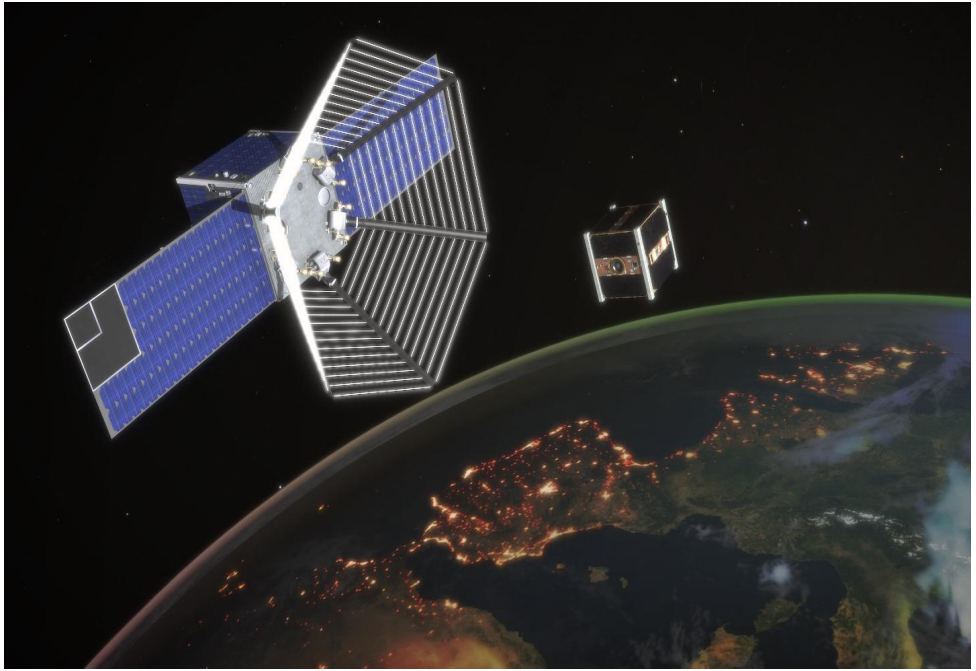
The team

- Username: EPFL_CVLAB
- Kyle Gerard
- Dr Mathieu Salzmann (CVLAB)
- Dr Yinlin Hu (CVLAB)



Why we participated

- Reduce space pollution
- CleanSpace One project to retrieve the swisscube
- eSpace

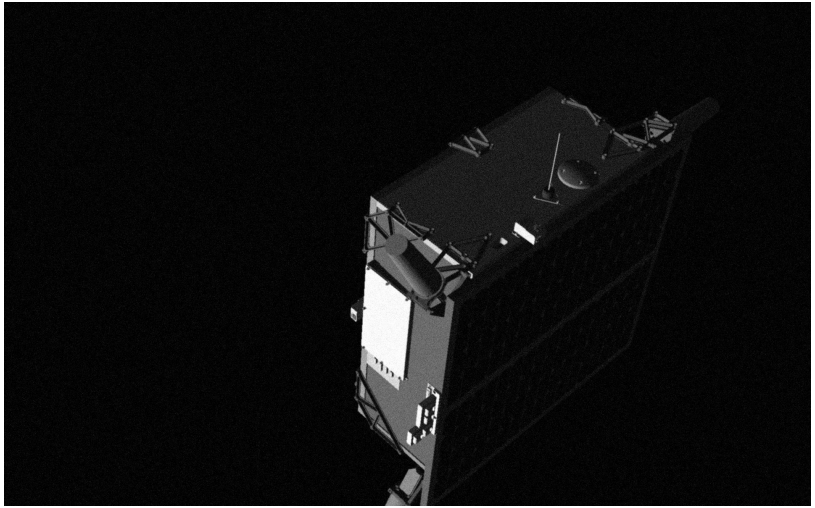


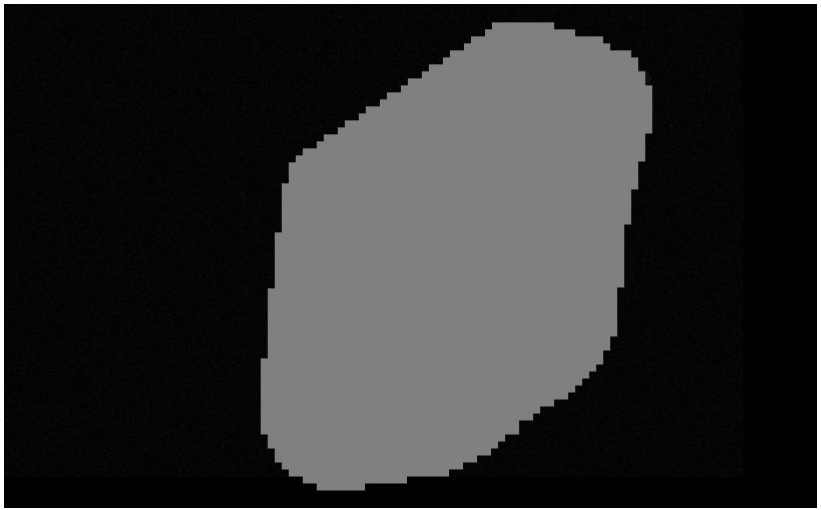
Approach

- Yinlin Hu, Joachim Hugonot, Pascal Fua and Mathieu Salzmann. Segmentation-driven 6D Object Pose Estimation. CVPR, 2019
- Darknet-53 architecture of YOLOv3 as the encoder
- Divided into grid where each cell makes predictions
- 2 stream architecture
- Cell votes/predictions are then fed to PnP algorithm to retrieve pose

Segmentation stream

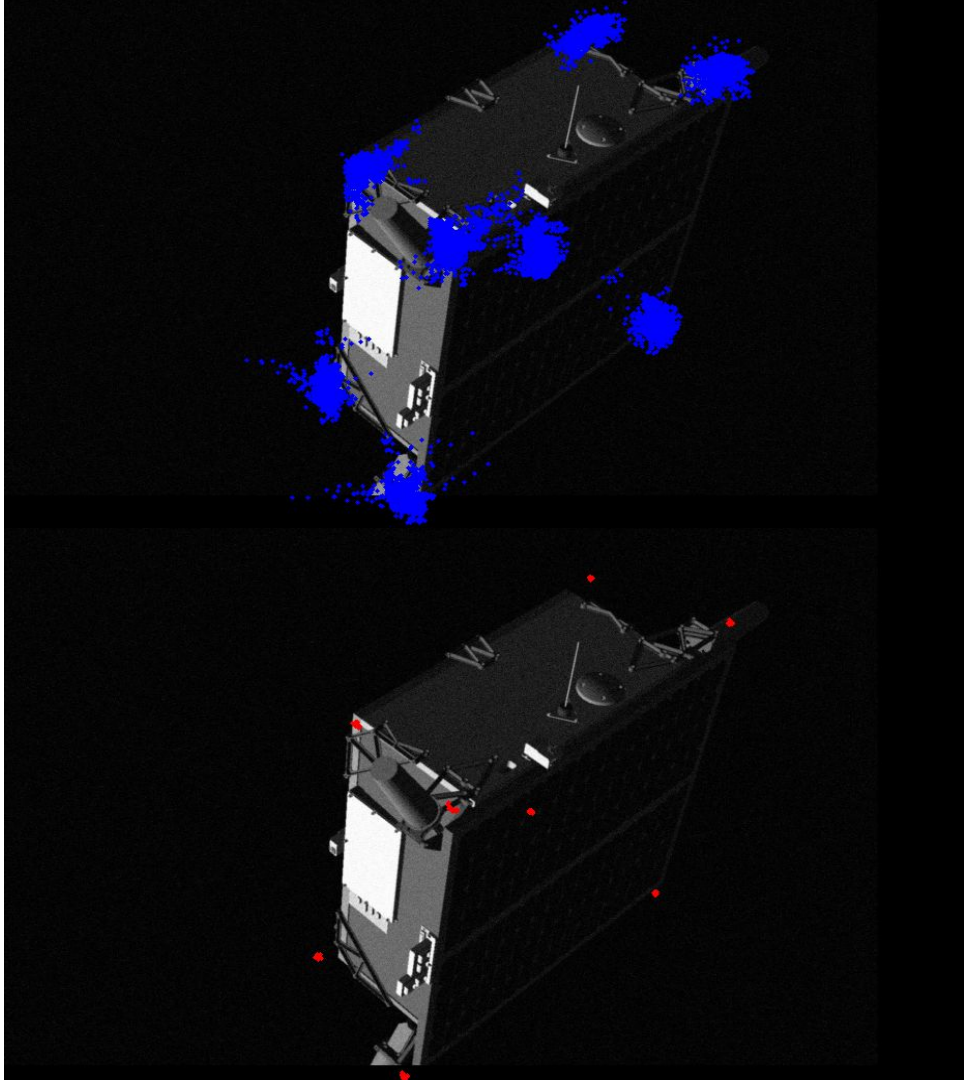
- Assign a label to each cell of the virtual S × S grid superposed on the image
- Uses Focal Loss because more background than object





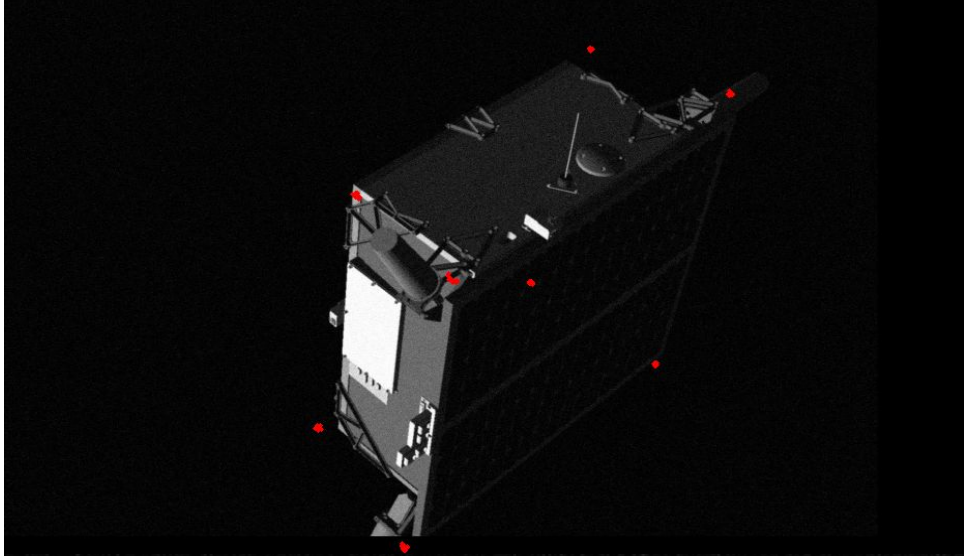
Regression stream

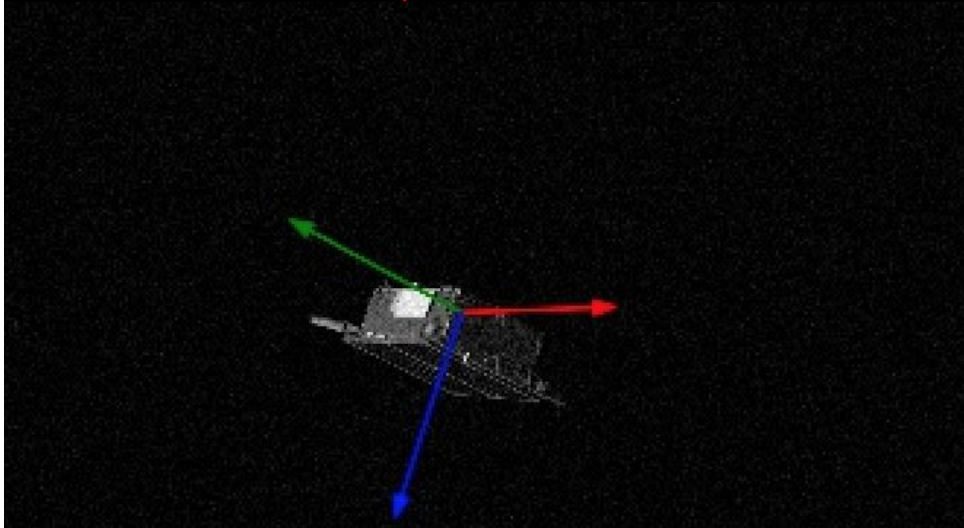
- Cells each predict relative 2D keypoints position
- L1 Loss of error distance
- Sigmoid function for confidence value
- Robust if satellite is damaged
- Confidence value is used to select n best 2D keypoint predictions



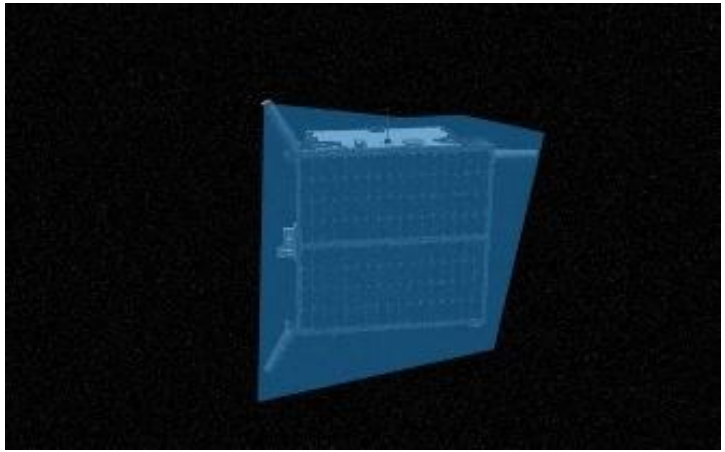
2D key points to 3D pose

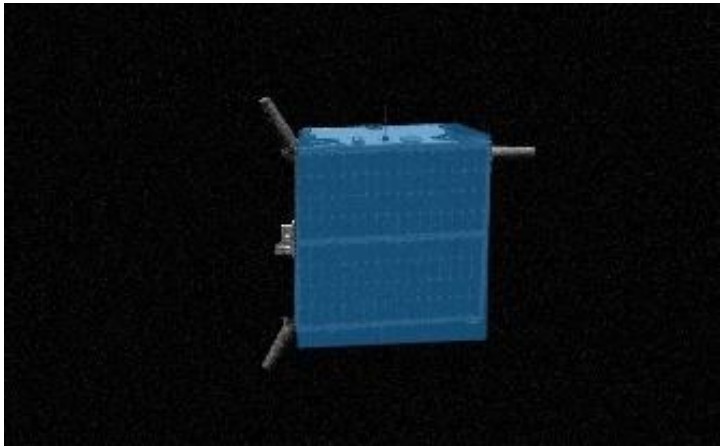
- Iterative PnP method
- RANSAC-based version of the EPnP developed at CVLAB to retrieve Pose



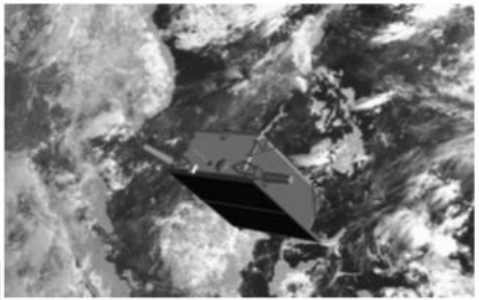


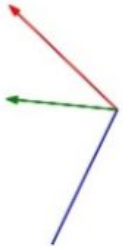
3D model of Tango satellite





Bounding Box + Segmentation bitmap

[a] 

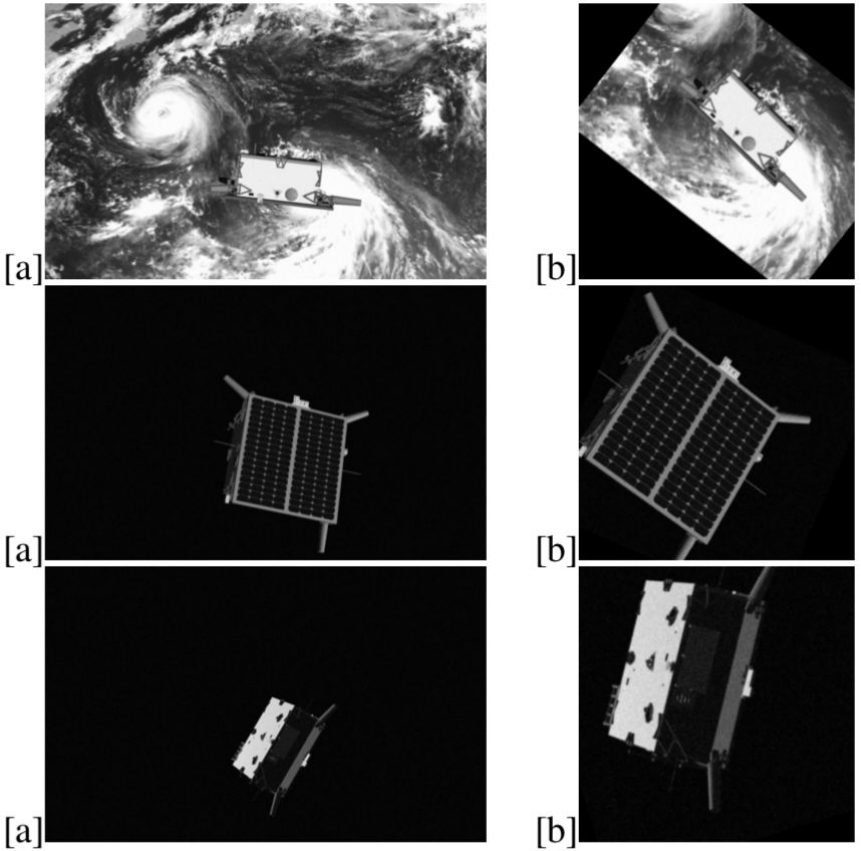
[b] 

[c] 

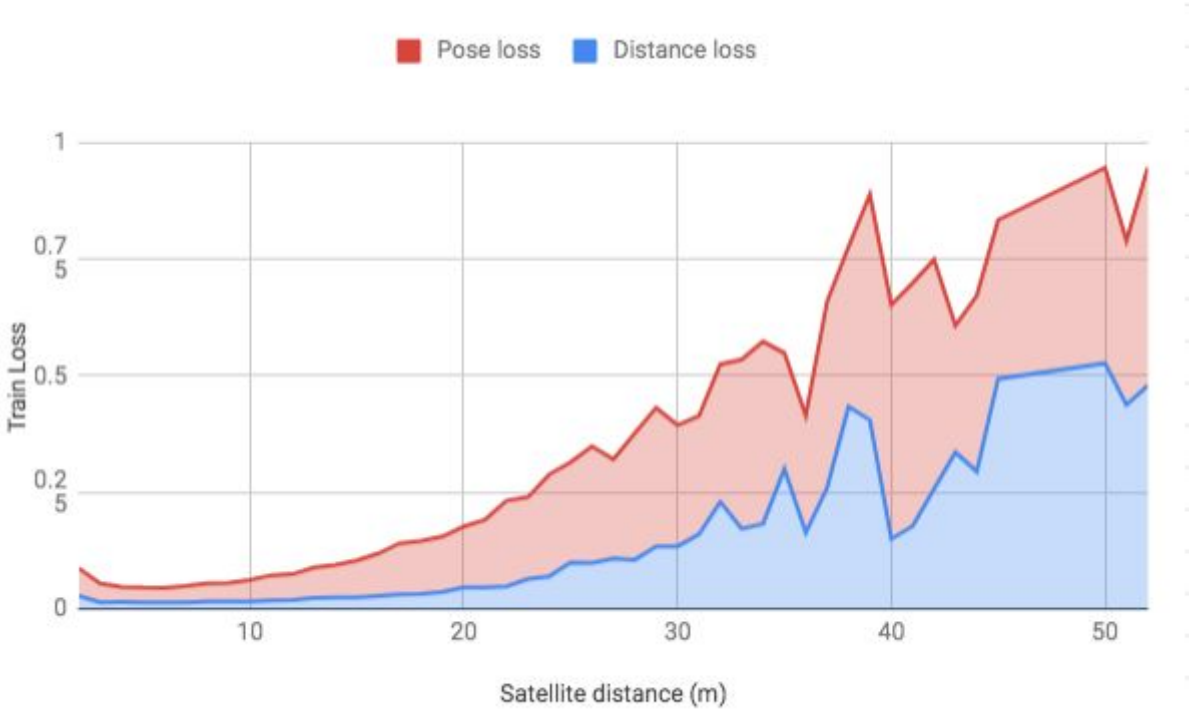
[d] 

Data Augmentation

- Rotation
- Random noise
- Zoom / Cropping



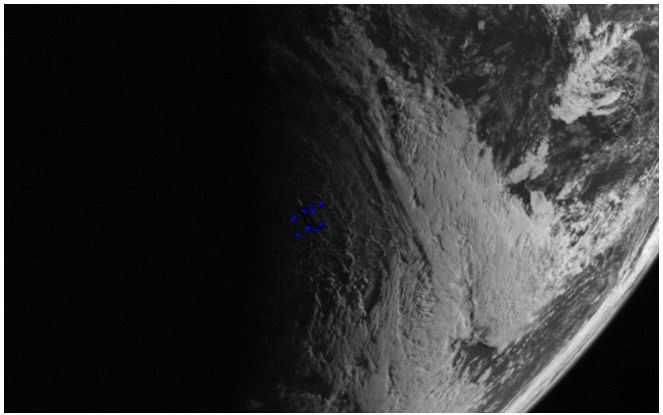
Full Image - Test score: 0.161

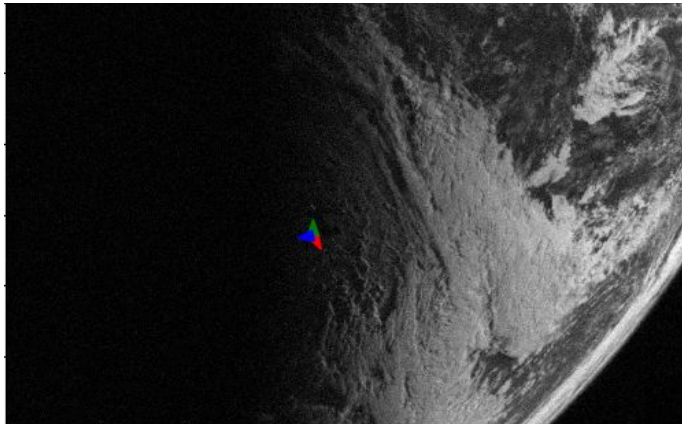


Zoom - Test score: below 0.05

PnP issues

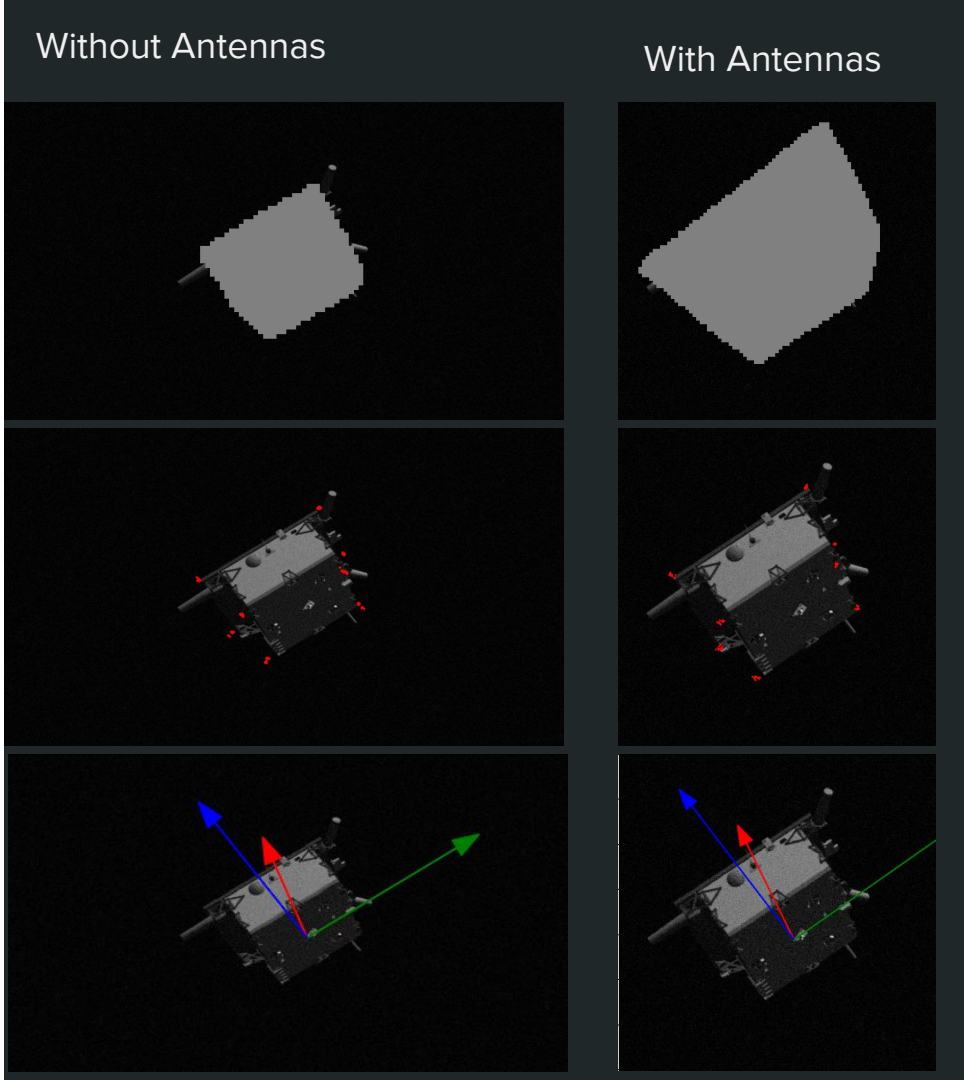
- Bad 2D keypoint prediction lead to absurd PnP results.
- Score of 1 image is unbounded -> Test Score of 2.99e+63...
- Detected using confidence value + range of possible satellite distances (satellite is between 3 and 50 meters away).



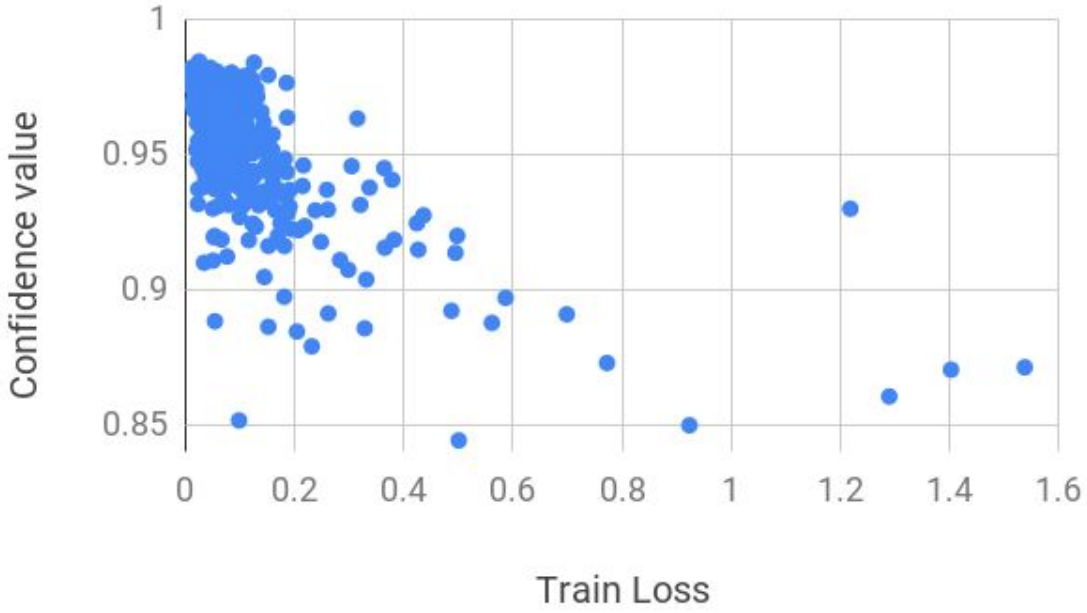


Comparison of the two 3D models

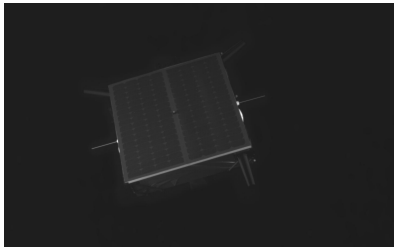
- model Without antennas: Best test score: 0.054
- Model with antennas score: Best test score 0.064

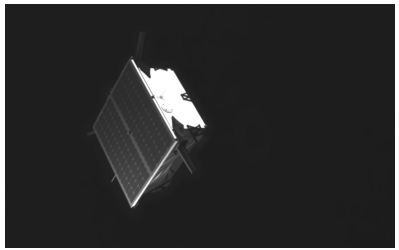


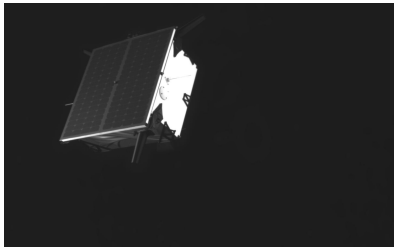
Competition optimizations - competition score: 0.02

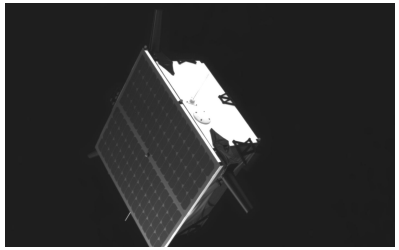


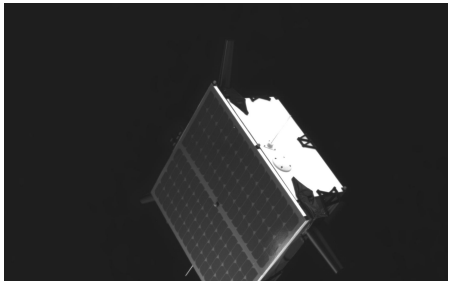
Real Images









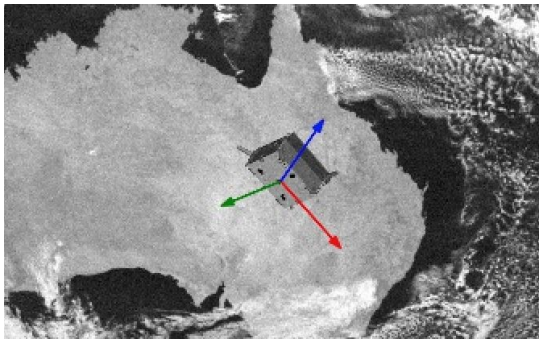


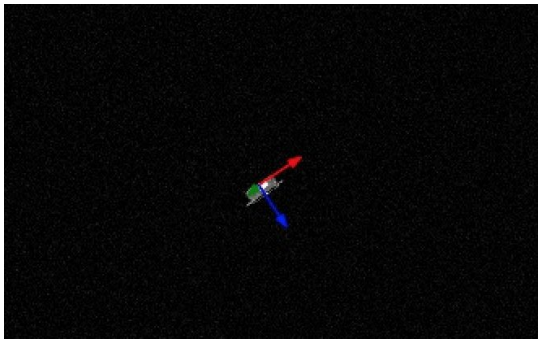
- 5 labelled images inserted to represent 10% of training images
- sufficient because real dataset is not very diverse
- Test score: 0.10
- no need for domain adaptation for real images

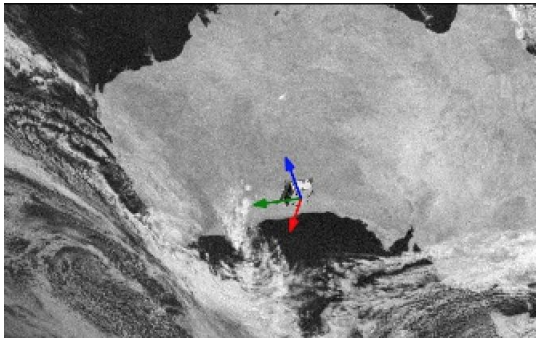
Results

Leaderboard

Name	Submissions	Last Submission	Best Submission	Real Image Score	Best Score
UniAdelaide	30	July 1, 2019, 5:59 a.m.	July 1, 2019, 5:59 a.m.	0.36340645622528017	0.00864899489025079
EPFL_cvlab	33	June 30, 2019, 7:34 p.m.	June 30, 2019, 12:24 a.m.	0.1040193712417902	0.020492797305239972
pedro_fairspace	22	July 1, 2019, 12:37 a.m.	July 1, 2019, 12:37 a.m.	0.1476264625490052	0.055458132121867405
stanford_slab	3	July 1, 2019, 5:54 a.m.	June 30, 2019, 6:16 a.m.	0.32214726966380525	0.06106161608221092
Team_Platypus	33	July 1, 2019, 5:46 a.m.	July 1, 2019, 5:46 a.m.	1.7117510190859844	0.06749196492840154
motokimura1	27	July 1, 2019, 5:35 a.m.	July 1, 2019, 5:35 a.m.	0.5713766945291576	0.07343483001842709
Magpies	29	July 1, 2019, 3:49 a.m.	July 1, 2019, 2:44 a.m.	1.2400904671292423	0.14294669930679743







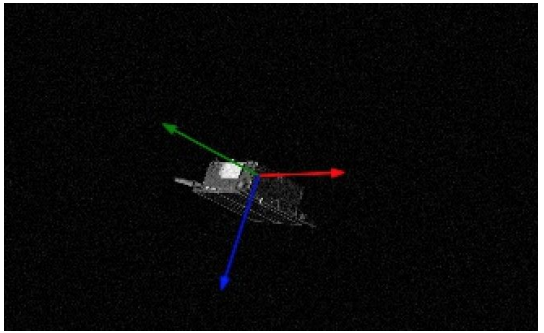
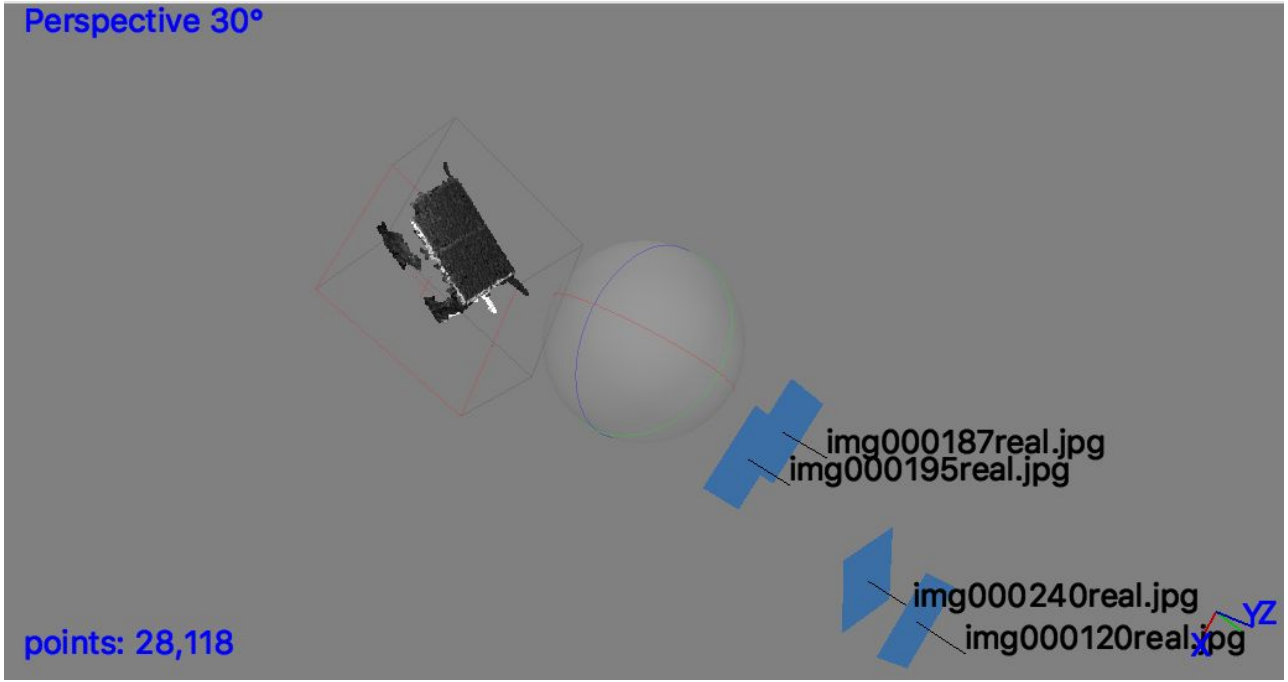


Photo reconstruction tools



Efforts to make model faster

Current model achieves 12 FPS on TITAN X GPU

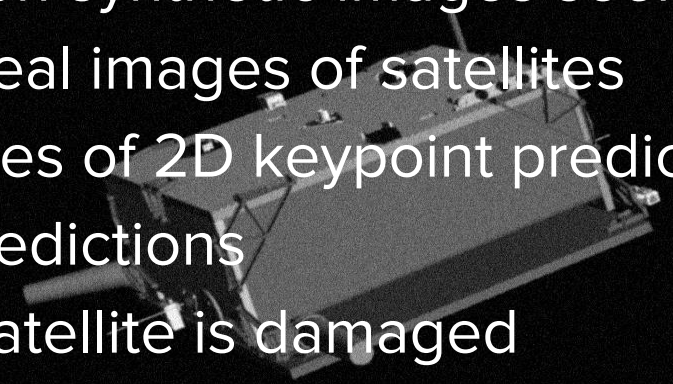
 needs to be faster to run on satellites

Solution:

- compact model
- optimizations
- FPGA

Conclusion

- It is possible to estimate satellite 6D pose accurately
- Very low resolution 3D models of objects are sufficient for the framework to be accurate
- Models trained on synthetic images seem to be transferable to real images of satellites
- Confidence values of 2D keypoint predictions are helpful to detect bad predictions
- Should work if satellite is damaged



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https://www.youtube.com/watch?v=JQpcqsXO14E

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