Camera Autocalibration using Predominantly Planar Aerial Imagery

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Video Links

https://youtu.be/7QhV2R64oDM

https://github.com/txoritxo/cs231a_Project/blob/main/presentation/cs231a_project_full.mp4

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Problem Statement

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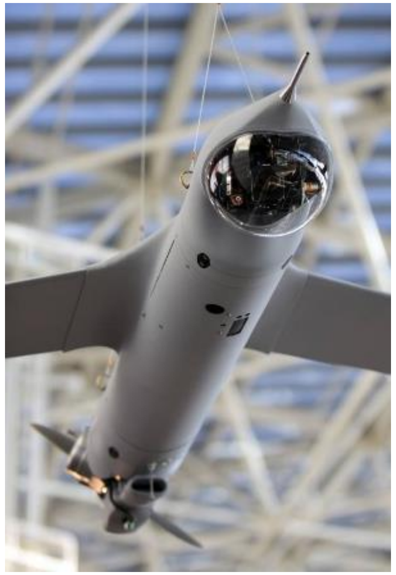
UAVs need to be able to navigate with onboard cameras.

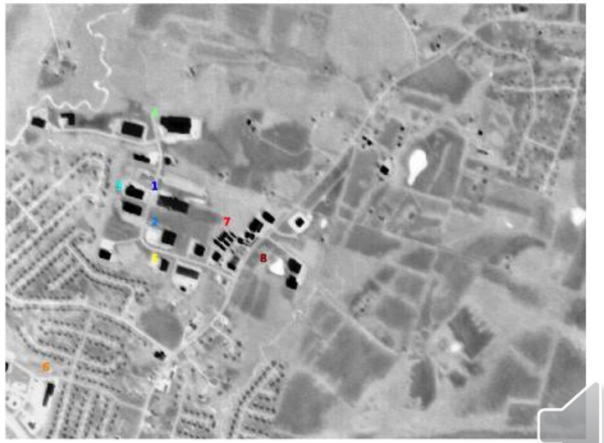


Accurate navigation is very sensitive to a good calibration though.

Temperature fluctuations, vibrations, zoom functionalities, etc. all can make a laboratory calibration invalid

Autocalibration in flight is a solution, yet at altitude, scene is mostly planar, making traditional methods inapplicable

Need to take advantage of the scene structure!
[Triggs '98] first presented a method specifically dedicated to planar scenes based upon inter-image homographies



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Technical Approach

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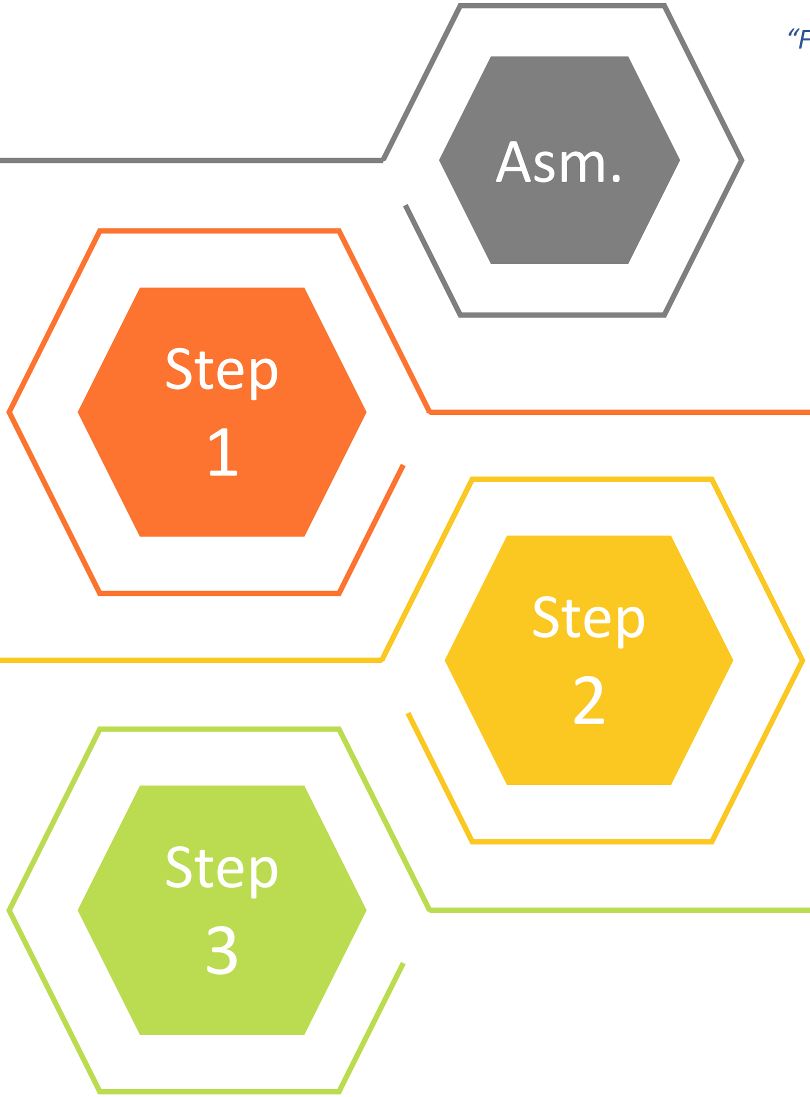
"Forget the checkerboard: practical self-calibration using a planar scene"
Herrera et. Al, WACV 2016



Assumptions

- Planar scene
- Camera
  - zero-skew
  - Radial distortion model

Feature Extraction & Matching

- SIFT feature extraction
- FLANN matching
- Filtering

Projective Reconstruction

- Homography estimation
- RANSAC

Projective Bundle Adjustment

- Initial estimation of distortion and Central Point
- Refinement of Homographies and world coordinates of scene points

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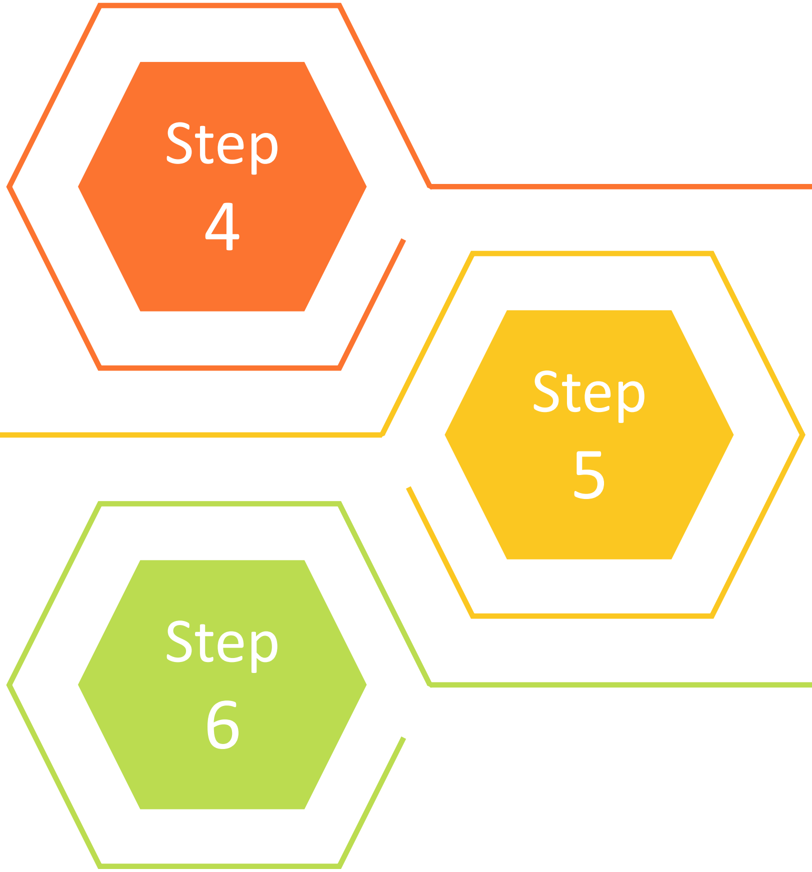

Homography based Self-Calibration

- Focal length estimation
- Non-linear minimization
- Principal point correction

Metric Reconstruction

- Initial extrinsic guess for reference frame
- Approximate 3D point coordinates in reference frame (triangulation)
- Extrinsic parameters for all frames using *PnP*

Metric Bundle Adjustment

- Minimization of reprojection errors
- Refine 3D scene point coordinates
- Refine intrinsics and distortion

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Results – Close Range Imagery

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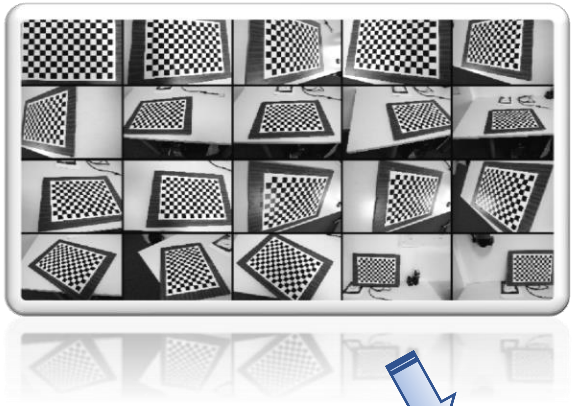
Baseline calibration

- DSLR + 18mm lenses
- Resized to 800x533 px
- Baseline: Checkerboard calibration
- Planar self-calibration: Poster Pictures
- Custom Python implementation



Matlab Calibration Toolbox

Custom planar self calibration method

Results

- Focal Length very accurate ~ 1.2%
- Less accurate Principal point ~ 2.5-6 %
- Reprojection error slightly better than Checkerboard
- High error in distortion, probably due to different Distortion models

		Checkerboard Cal.	Planar Self-Cal.	Deviation(%)
Focal Length	fx	657.611 (18.25 mm)	664.954 (18.45 mm)	1.12
	fy	658.268 (18.27 mm)	666.036 (18.49 mm)	1.18
Principal Point	u	401.66	425.684	5.98
	v	289.896	283.173	2.32
Distortion	d0	-1.76E-01	3.75E-07	100.00
	d1	1.04E-01	3.96E-13	100.00
Pixel Error		0.65	0.58	10.28

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Results on real aerial imagery

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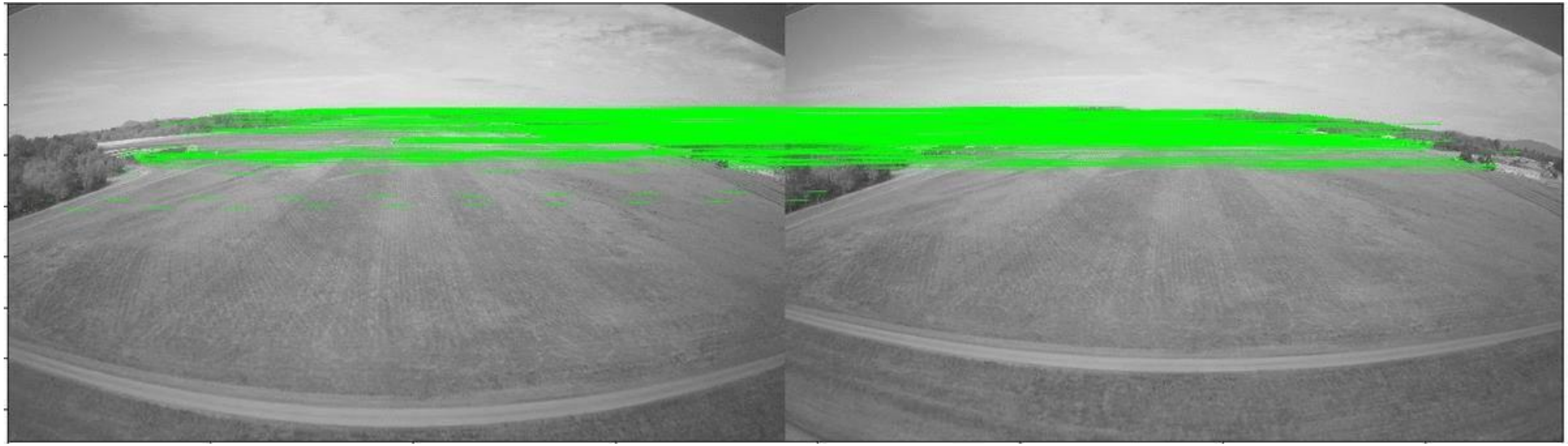

- Real flight imagery from landing maneuver at Sanderson Field Airport (Washington).
- 4K resolution images taken with GoPro camera (forward-looking).
- Real lenses with radial + tangential distortion.

	Autocalibration	Ground Truth	Error [%]
f_x	1766.25 px	1749.42 px	**0.94**
f_y	1765.00 px	1747.92 px	**0.98**
c_x	1916.59 px	1891.50 px	1.3
c_y	1085.18 px	1085.92 px	**-0.07**
d_0	-0.206	-0.268	23.1
d_1	0.0001	0.011	-

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Results – Satellite Imagery

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osgEarth **is used to transform satellite orthoimagery to a given virtual camera perspective**

		Specified Cal.	Planar Self-Cal.	Deviation(%)
Focal Length	fx	1117.65	1527.25	36.7
	fy	1117.65	1455.30	30.3
Principal Point	u	511.5	480.65	6.0
	v	383.5	415.15	8.3
Distortion	d0	0	-3.29E-09	-
	d1	0	-1.2515E-14	-
Pixel Error		N/A	0.07	-

Measures to improve numerical conditioning for optimization: normalized feature points, program Jacobians for bundle adjustments, select homographies with best condition numbers

Poor results 🥺
Large estimation errors even though plane is performing roll maneuver in sample images, i.e. rotation + translation.

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Conclusions

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[Herrera '16] Autocalibration fully implemented in Python

Close-range imagery results: Promising results with checkerboard in comparison with standard methods. Distortion model fitting plays important role.

Runway imagery results: Very promising results with real flight imagery in special landing case. Good use case!

High altitude imagery results: Suspect too close to degenerate case of pure translation between views of planar imagery.

Real flight imagery with perpendicular view

Need to further take advantage of the scene structure to get yet better results for this application.
[Yang '19] presented a method specifically dedicated to autocalibrate planar scenes with pure translational movement