Camera Drones
Lecture – Flight planning

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WS 2021

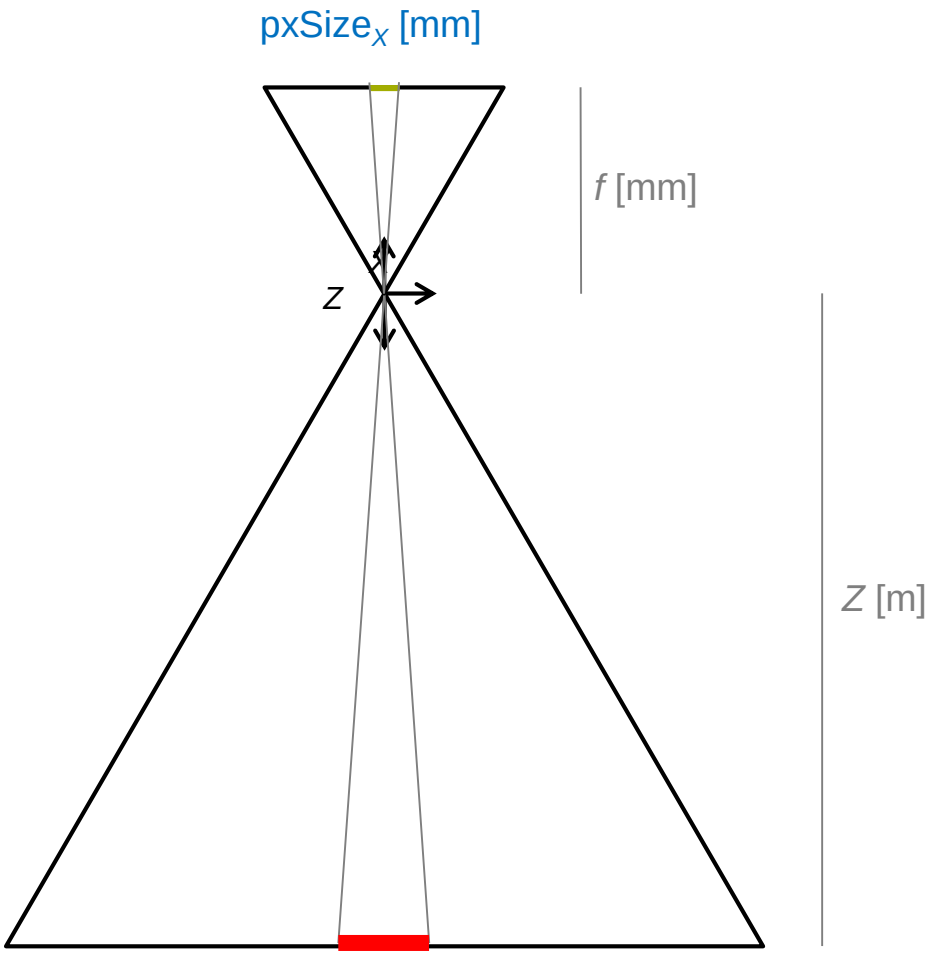
Outline

- Flight planning
  - Ground sampling distance (GSD)
  - Field-of-view (FOV)
  - Depth uncertainty
  - Overlap

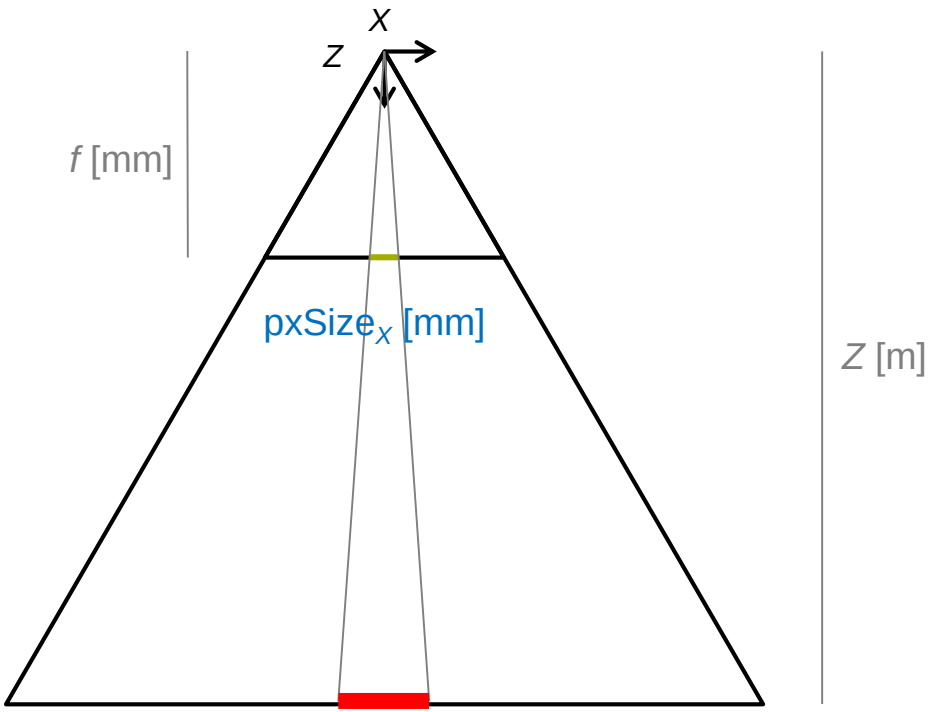
Flight planning

- Ground sampling distance (GSD)
  - Ground resolution in meter (What is the size of an image pixel on the ground)
  - Defined by image resolution, lens (focal length) and height
- Field-of-View (FOV)
  - Angular section of the scene which is visible in the image (measured in degrees)
- Overlap
  - Percentage of same image content from two neighboring images
  - Important for image matching and stereo
  - Defined by movement between two neighboring images
- Depth uncertainty
  - Depending on the distance from the camera, triangulation results have a different accuracy

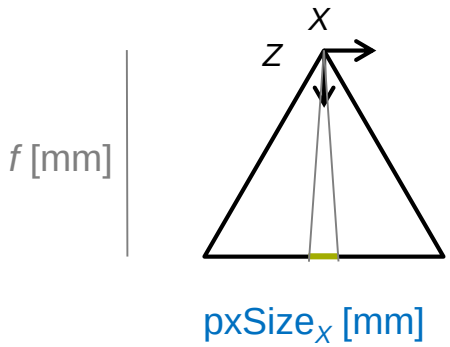
Camera projection

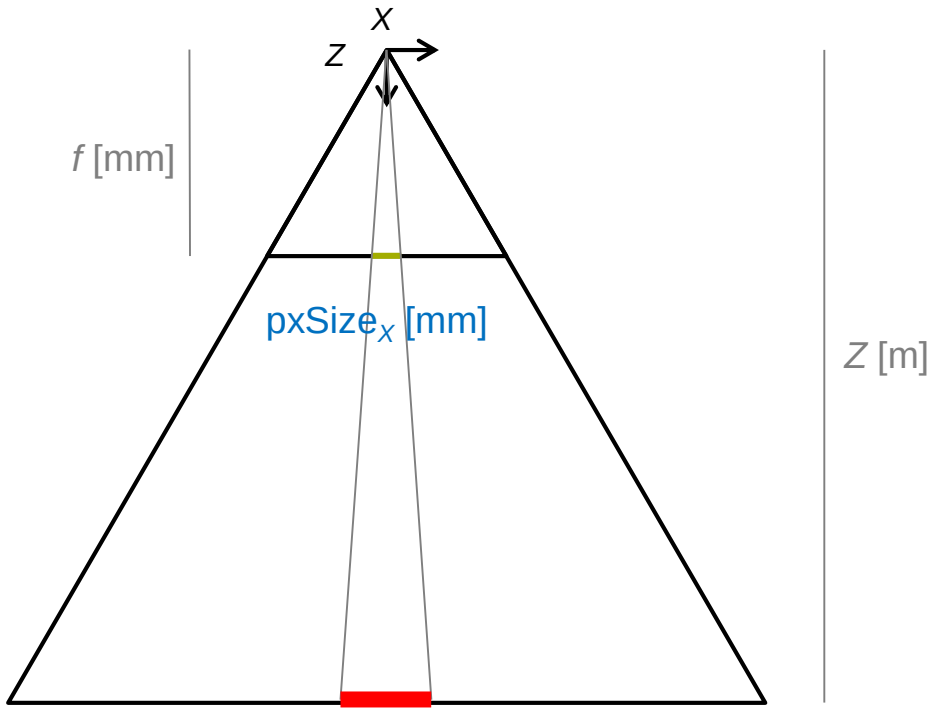


Camera projection



Ground sampling distance

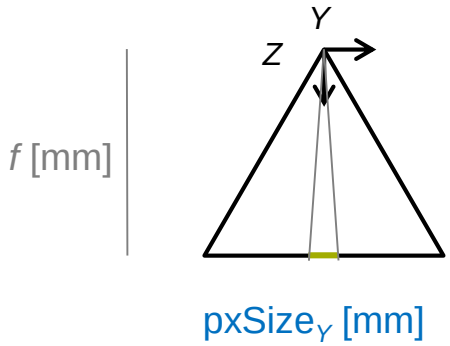


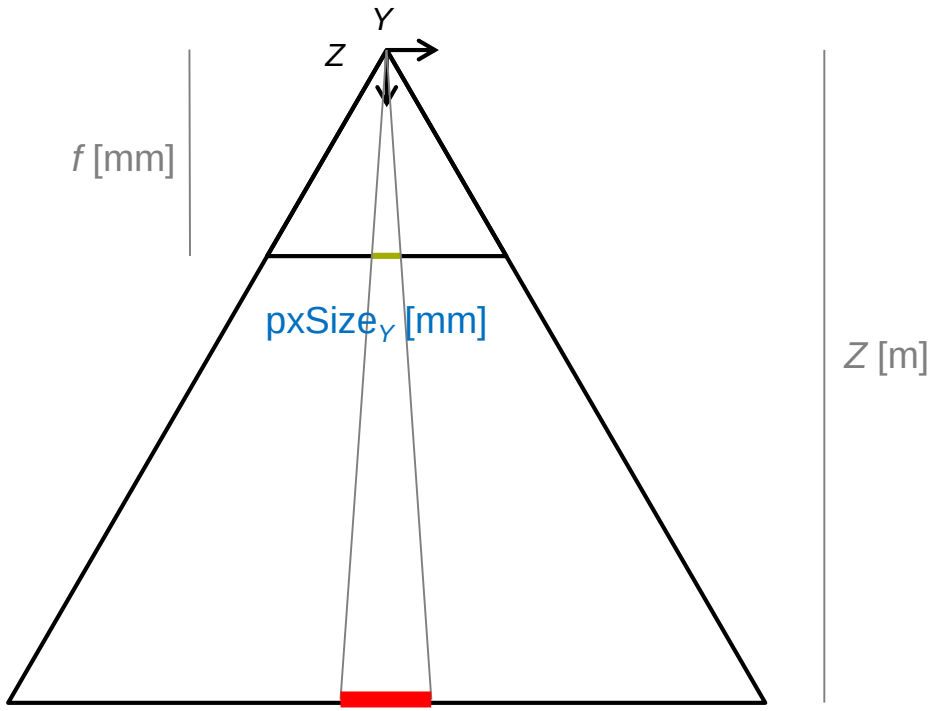


GSD$_X$ [m]
focal length *f* [mm]
depth *Z* [m] (= height *h* [m] for nadir camera)
pxSize$_X$ [mm]

$$GSD_X\ [m] = Z\ [m] * pxSize_X\ [mm] / f\ [mm]$$

Ground sampling distance





GSD$_Y$ [m]
focal length *f* [mm]
depth *Z* [m] (= height *h* [m] for nadir camera)
pxSize$_Y$ [mm]

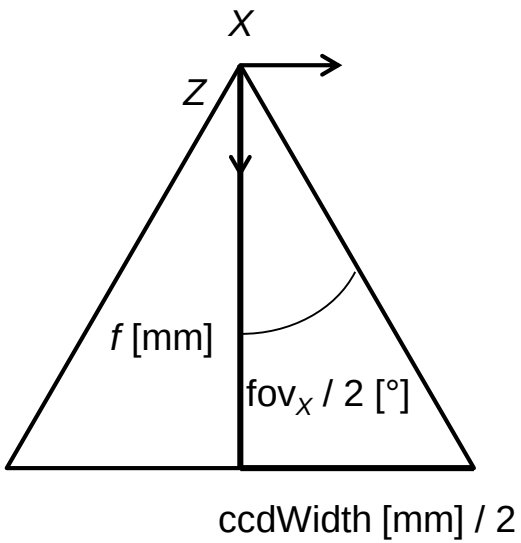
Cameras typically have square pixels
GSDx = GSDy

$$GSD_Y\ [m] = Z\ [m] * pxSize_Y\ [mm] / f\ [mm]$$

Field-of-view (FOV)

- Field-of-view determines how much of a scene you will see in the image
- FOV can be computed from focal length and chip size

fov_X [rad]
focal length *f* [mm]
ccdWidth [mm]

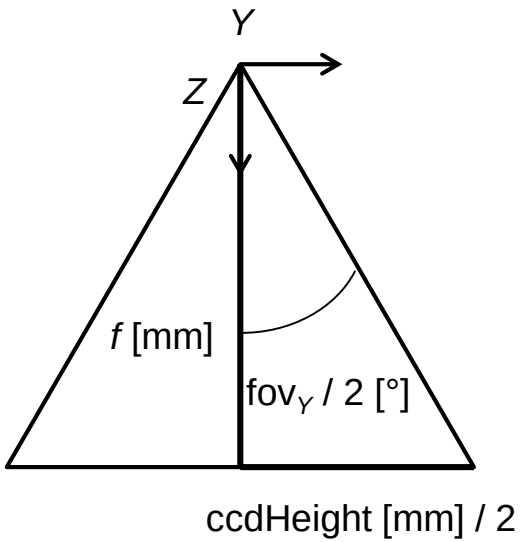


$$fov_X = 2 * \tan^{-1}((ccdWidth / 2) / f)$$

Field-of-view (FOV)

- CCD chip is not quadratic, FOV is different in x/y direction

fov_Y [rad]
focal length *f* [mm]
ccdHeight [mm]



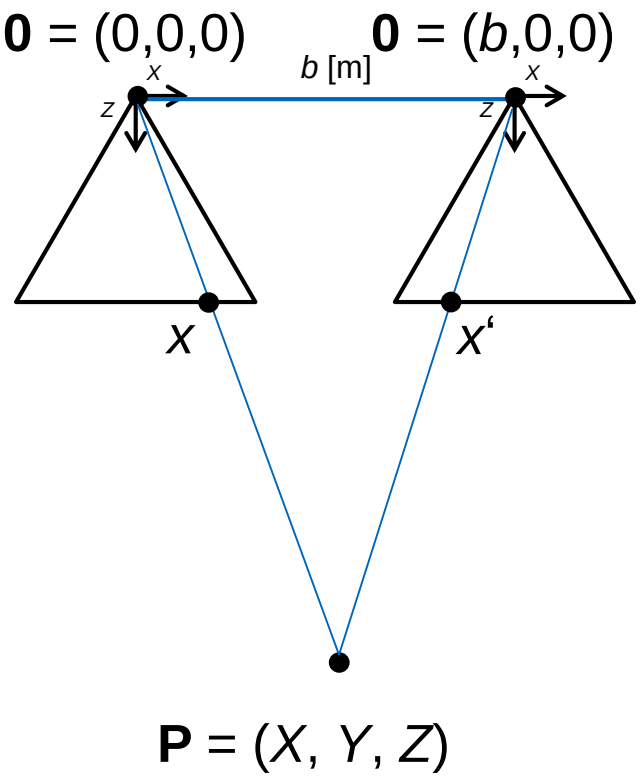
$$fov_Y = 2 * \tan^{-1}((ccdHeight / 2) / f)$$

Depth Uncertainty e_Z [m]

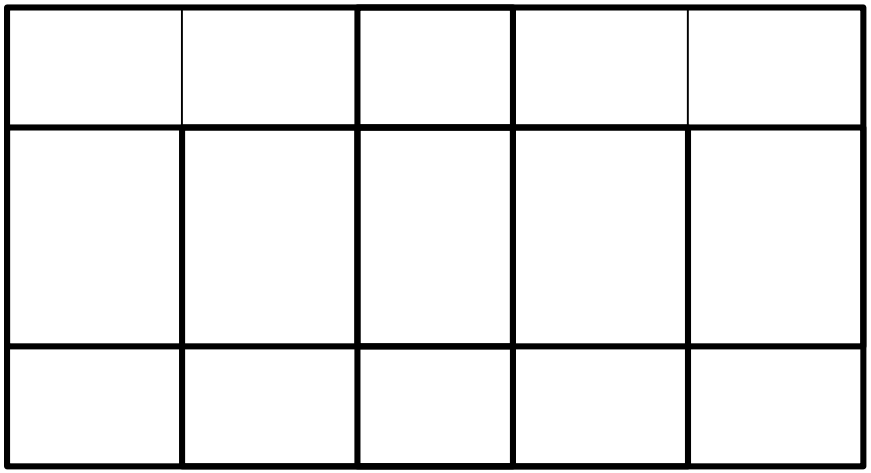
d … disparity [pixel]
f .. focal length [pixel]
m .. disparity uncertainty [pixel]

$$\frac{z}{f} = \frac{b}{d}$$

$$\Delta z = \frac{z^2}{fb} m$$

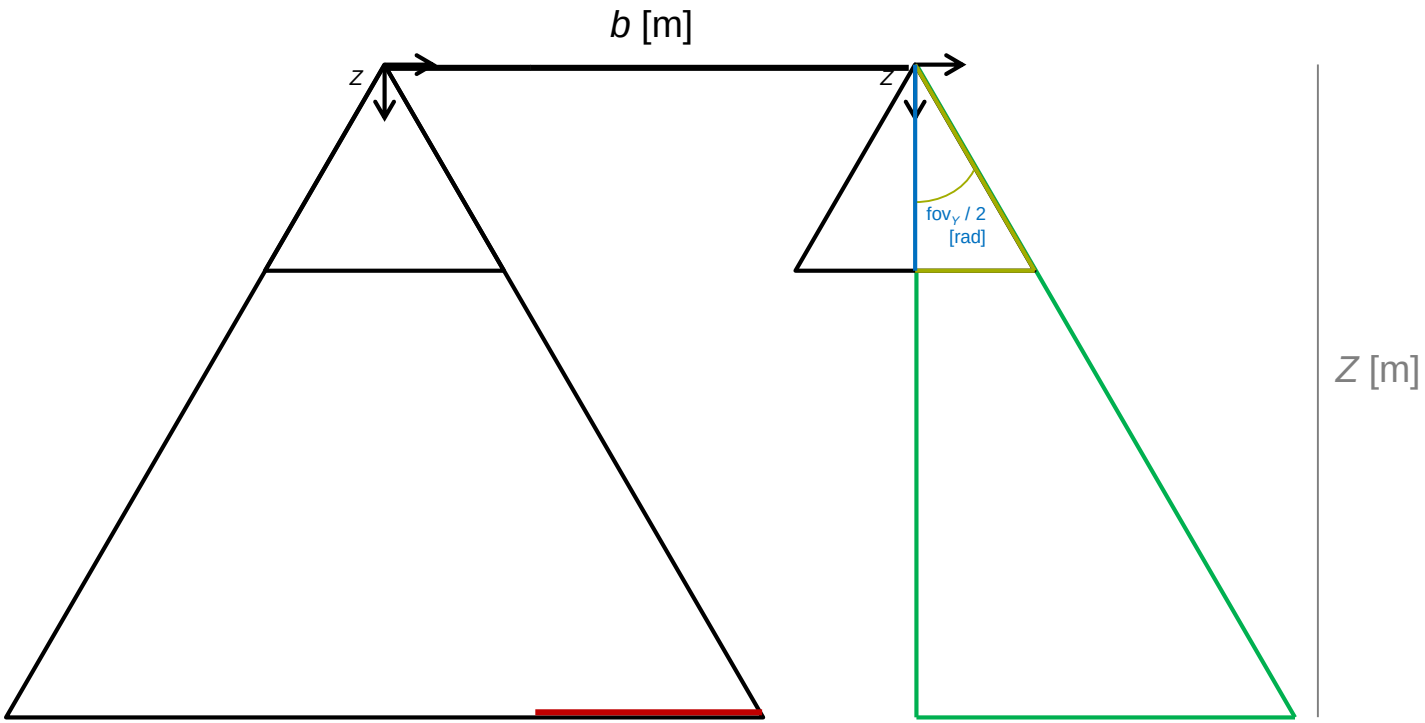


Overlap



- Photogrammetry standard 80% overlap (low!)

Overlap



$$\frac{2 * Z * \tan(\text{fov}_Y / 2) - b}{2 * Z * \tan(\text{fov}_Y / 2)}$$

Example calculation

- Sony Nex5N
  - Sensor dimension w: 23.5mm, h:15.6mm
  - Image resolution: 4912x3264 pixel
  - Focal length 18mm

- FOV:
  - x: $2 * \tan^{-1}((ccdWidth / 2) / f) = 2 * \tan^{-1}((23.5 / 2) / 18) = 66.3$ deg
  - y: $2 * \tan^{-1}((ccdHeigth / 2) / f) = 2 * \tan^{-1}((15.6 / 2) / 18) = 46.9$ deg

- GSD (100m)
  - *x:* Z [m] * $pxSize_X$ [mm] / f [mm] = 100*23.5/4912/18=0.027m=2.7cm
  - *y:* Z [m] * $pxSize_Y$ [mm] / f [mm] = 100*15.6/3264/18=0.027m=2.7cm

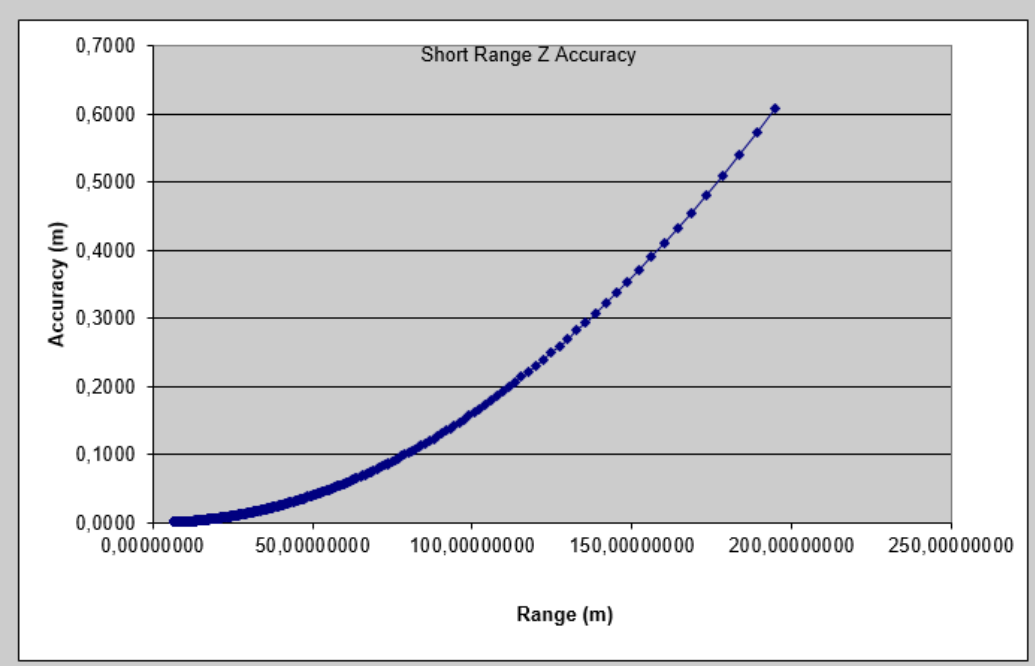
Example calculation

height above ground (z) [m]	GSD [m]
20	0,0053
25	0,0066
30	0,0080
35	0,0093
40	0,0106
45	0,0119
50	0,0133
55	0,0146
60	0,0159
65	0,0173
70	0,0186
75	0,0199
80	0,0212
85	0,0226
90	0,0239
95	0,0252
100	0,0266

Example calculation

- Depth uncertainty (1m baseline)
- Disparity uncertainty 0.1px

Disparity	Z (m)	Z accuracy (m)
1	6238,24000000	623,8240
1,5	4158,82666667	277,2551
2	3119,12000000	155,9560
2,5	2495,29600000	99,8118
3	2079,41333333	69,3138
3,5	1782,35428571	50,9244
4	1559,56000000	38,9890
4,5	1386,27555556	30,8061
5	1247,64800000	24,9530
6	1039,70666667	17,3284
7	891,17714286	12,7311
8	779,78000000	9,7473
9	693,13777778	7,7015
10	623,82400000	6,2382



Example calculation

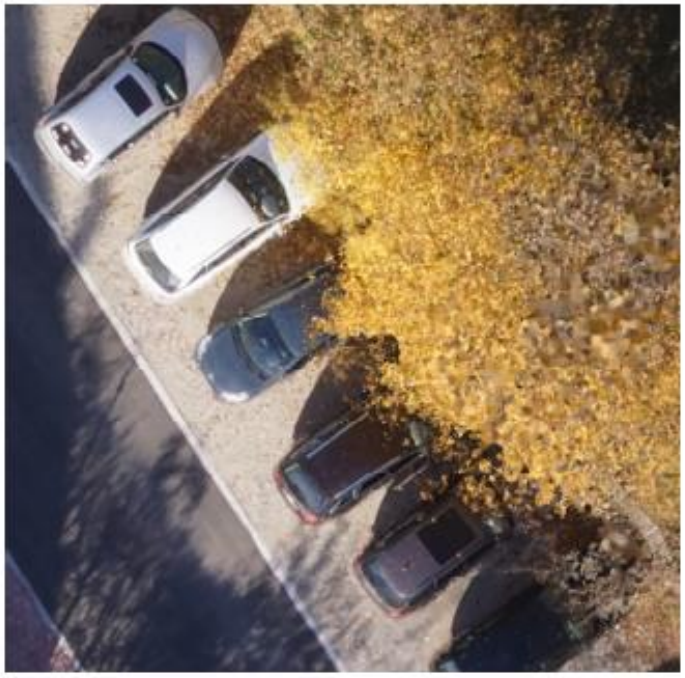
- Distance between images to achieve 80% overlap in 100m height
- Calculating b
- Z = 100m
- FOVy=46.9deg

$$\frac{2 * Z * \tan(fov_Y / 2) - b}{2 * Z * \tan(fov_Y / 2)} = 0.8$$

$$b=2 * Z * \tan(fov_Y / 2) - 0.8*2 * Z * \tan(fov_Y / 2) = 17.36m$$

Comparison UAV and aerial image

Dataset	Reference image				Target image			
	Type/Date	Resolution	height (m)	GSD (cm)	Type/Date	Resolution	height (m)	GSD (cm)
Eichenau	AO 11/2015	9206 × 7357	600	20	UI 11/2015	573 × 794	100	1.8
Germering	AI 06/2014	5184 × 3902	700	9.4	UI 07/2014	823 × 996	100	2
EOC	AI 06/2014	5184 × 3902	340	4.6	UI 11/2014	1106 × 807	25-40	0.5-0.8
WV2	SI 2010	5292 × 6410	770, 000	46	AI 2015	497 × 332	350	4.4



Exercises

Exercise 1

- The camera of a drone has a GSD of 2.7cm at a height of 100m with its 18mm lens. If the lens is changed to a 10mm lens, will the GSD be larger or smaller?

- Sony Nex5N
  - Sensor dimension w: 23.5mm, h:15.6mm
  - Image resolution: 4912x3264 pixel

Exercise 2

- What are the footprint dimensions (in x and y direction) of a camera with the following parameters at 50m height?

- Sony Nex5N
  - Sensor dimension w: 23.5mm, h:15.6mm
  - Image resolution: 4912x3264 pixel
  - Focal length: 18mm