Camera Drones
Lecture – Flight planning

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WS 2020
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

\[ \text{pxSize}_x [\text{mm}] \]

\[ f [\text{mm}] \]

\[ Z [\text{m}] \]
Camera projection

\[ f \text{ [mm]} \]

\[ \text{pxSize}_x \text{ [mm]} \]

\[ Z \text{ [m]} \]
Ground sampling distance

\[
GSD_X [m] = Z [m] \times \text{pxSize}_X [mm] / f [mm]
\]
Ground sampling distance

\[
GSD_Y [m] = Z [m] \times \text{pxSize}_Y [mm] / f [mm]
\]

GSD \_Y [m]

focal length \( f \) [mm]

depth \( Z \) [m] (= height \( h \) [m] for nadir camera)

\text{pxSize}_Y [mm]

Cameras typically have square pixels

\( \text{GSD}_x = \text{GSD}_y \)
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

\[
\text{fov}_X = 2 \cdot \tan^{-1}\left(\frac{\text{ccdWidth}/2}{f}\right)
\]

\(\text{fov}_X\) [rad]

focal length \(f\) [mm]

ccdWidth [mm]
Field-of-view (FOV)

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

\[
\text{fov}_Y = 2 \times \tan^{-1}\left(\frac{\text{ccdHeight} / 2}{f}\right)
\]
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

\[ 2 \times Z \times \tan(\text{fov}_Y / 2) - b \]

\[ 2 \times Z \times \tan(\text{fov}_Y / 2) \]

\[ Z \times \tan(\text{fov}_Y / 2) \]
Example calculation

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

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

- **GSD (100m)**
  - x: \(Z[m] \times \text{pxSize}_X[\text{mm}] / f[\text{mm}] = 100 \times 23.5 / 4912 / 18 = 0.027\) m = 2.7cm
  - y: \(Z[m] \times \text{pxSize}_Y[\text{mm}] / f[\text{mm}] = 100 \times 15.6 / 3264 / 18 = 0.027\) m = 2.7cm
## Example calculation

<table>
<thead>
<tr>
<th>height above ground (z) [m]</th>
<th>GSD [m]</th>
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<tbody>
<tr>
<td>20</td>
<td>0.0053</td>
</tr>
<tr>
<td>25</td>
<td>0.0066</td>
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<tr>
<td>30</td>
<td>0.0080</td>
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<tr>
<td>35</td>
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<tr>
<td>40</td>
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<tr>
<td>45</td>
<td>0.0119</td>
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<tr>
<td>50</td>
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<td>55</td>
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<tr>
<td>95</td>
<td>0.0252</td>
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<tr>
<td>100</td>
<td>0.0266</td>
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</tbody>
</table>
Example calculation

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

<table>
<thead>
<tr>
<th>Disparity</th>
<th>Z (m)</th>
<th>Z accuracy (m)</th>
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<tbody>
<tr>
<td>1</td>
<td>6238.24000000</td>
<td>623.8240</td>
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<td>1,5</td>
<td>4158.82666667</td>
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<td>2</td>
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<td>10</td>
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</table>
Example calculation

- Distance between images to achieve 80% overlap in 100m height
- Calculating b
- $Z = 100m$
- $\text{FOV}_y = 46.9\,\text{deg}$

\[
2 \times Z \times \tan\left(\frac{\text{FOV}_y}{2}\right) - b = 0.8
\]

\[
b = 2 \times Z \times \tan\left(\frac{\text{FOV}_y}{2}\right) - 0.8 \times 2 \times Z \times \tan\left(\frac{\text{FOV}_y}{2}\right) = 17.36m
\]
Comparison UAV and aerial image

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Reference image</th>
<th>Target image</th>
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<tbody>
<tr>
<td></td>
<td>Type/Date</td>
<td>Resolution</td>
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<tr>
<td>Germering</td>
<td>AI 06/2014</td>
<td>5184 × 3902</td>
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<tr>
<td>EDC</td>
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<td>WV2</td>
<td>SI 2010</td>
<td>5292 × 6410</td>
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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