# Pixel Ground Size Computation

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**Abstract**

This document is part of the supplementary material for our RA-L + ICRA 2022 submission entitled *Runtime Monitoring for UAV Urban Emergency Landing*. It shows in details how the ground size corresponding to a given pixel in the studied image is computed.

## 1 Preliminary

The main assumption used is that the pixel size is considered equal for all pixels belonging to the same row of the image. For a given row $i$, we want to express the size of a pixel $\delta_i$ in terms of:

- UAV height $H$,
- UAV camera angle $\theta$,
- camera sensor width $w$, height $h$ and focal length $f$,
- image width $I_w$ and height $I_h$.

In addition, the following notations are introduced to improve readability:

- $d$, distance between UAV and ground point corresponding to image center,
- $D$, ground distance corresponding to image height,
- $d_i$ distance between UAV and ground point corresponding to center pixel of row $i$,
- $W_i$, ground distance corresponding to row $i$,
- $h_i = i/I_h$, the normalized height of row $i$.

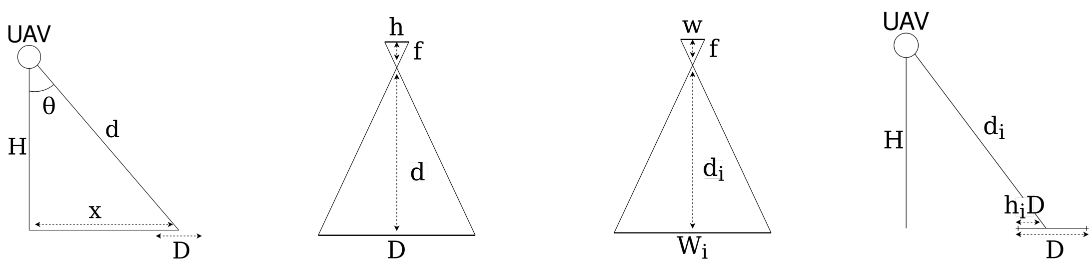
To ease understanding, these notations are represented schematically in Figure 1.

## 2 Computing pixel ground size

Then, from Figure 1a, we get

$$x = H \tan\theta, \tag{1}$$

$$d = H \cos\theta. \tag{2}$$




(a) (b) (c) (d)

Figure 1: Helper figures

From Figure 1b and Equation 2, we have

$$D = \frac{hH\cos\theta}{f}, \tag{3}$$

and similarly, from Figure 1c

$$W_i = \frac{wd_i}{f}. \tag{4}$$

Finally, Figure 1d gives us

$$d_i = \sqrt{H^2 + \left(x - \frac{1}{2}D + h_i D\right)^2} = \sqrt{H^2 + \left(x + \left(h_i - \frac{1}{2}\right) D\right)^2} \tag{5}$$

By injecting Equations 1, 3 into Equation 5, and Equation 5 into Equation 4, we get

$$W_i = \frac{w}{f}\sqrt{H^2 + \left(H\tan\theta + \left(\frac{i}{I_h} - \frac{1}{2}\right)\frac{hH\cos\theta}{f}\right)^2}, \tag{6}$$

which can be simplified as

$$\boxed{W_i = \frac{wH}{f}\sqrt{1 + \left(\tan\theta + \left(\frac{i}{I_h} - \frac{1}{2}\right)\frac{h\cos\theta}{f}\right)^2}}. \tag{7}$$

Following our assumption of equal sized pixels within a row, the pixel size for row $i$ can then be computed as follows:

$$\boxed{\delta_i = \frac{W_i}{I_w}}. \tag{8}$$

# 3 Image characteristics in our paper

In our paper, we use images from the UAVid dataset [1], which have the following characteristics:

- They are collected with the default camera of a Phantom 4 UAV, i.e., $w = 13.2$mm, $h = 8$mm and $f = 8.8$mm.
- The drone flies at $H \approx 50$ meters and the camera is fixed with an angle $\theta \approx 45°$.
- After resizing, the images have the following shape $I_h = 576$ and $I_w = 1024$ (in pixels).

# References

[1] Y. Lyu, G. Vosselman, G.-S. Xia, A. Yilmaz, and M. Y. Yang, "Uavid: A semantic segmentation dataset for uav imagery," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 165, pp. 108–119, 2020.