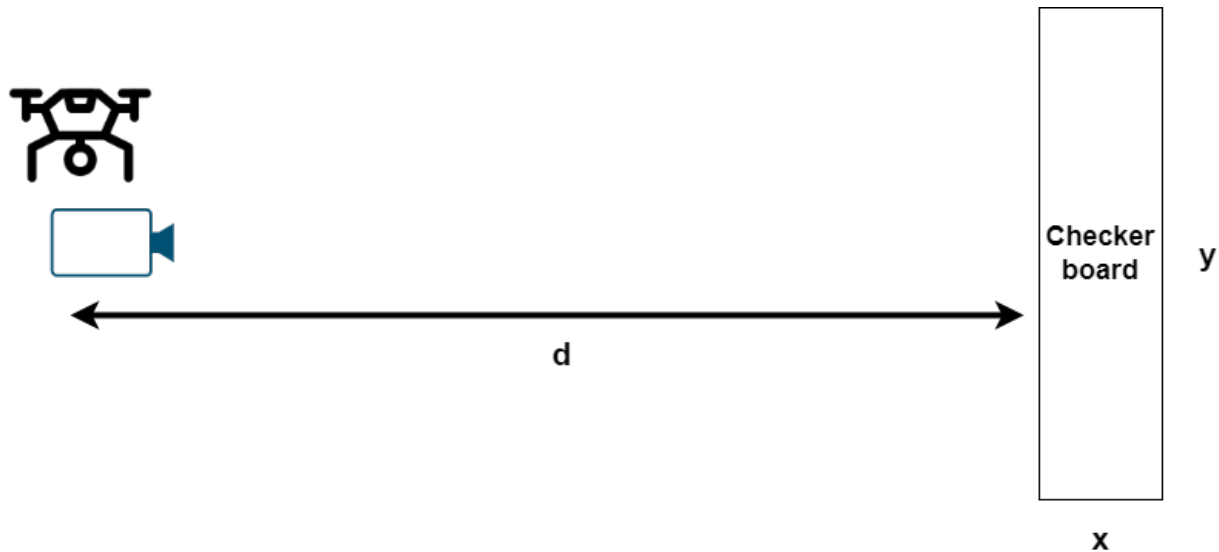


GSD estimation test report

$$\text{GSD} = \text{Sensor Width (mm)} * \text{Working Distance (m)} / \text{True Focal Length} * \text{Image Width (pixels)}$$

Test plan



Description:

By using the camera on the drone to capture photos of the checkerboard on the wall, with known dimension of the checkerboard and measured distance between the drone and the checkerboard, the GSD can be obtained using the formula above.

By measuring number of pixels of the dimensions (width and height) of the checkerboard in the image, times GSD (m/pixels), we can obtain the estimated dimension of the object in an image, and compare with the actual value.

Observation

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0087	3	W	16.94	168	18.48	9%
		H	21.78	217	23.87	10%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0088	5	W	16.94	102	18.36	8%
		H	21.78	132	23.76	9%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0089	7	W	16.94	75	18.75	11%
		H	21.78	95	23.75	9%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0090	9.65	W	16.94	55	19.25	14%
		H	21.78	72	25.2	16%

There are in average 11% error between the estimated and actual dimension of the checkerboard. No significant difference when the distance between the drone and the wall is increased except when the distance is up to around 10m. The estimation becomes inaccurate when the drone is 10m apart from the object.

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0087	3	W	16.94	168	18.48	9%
		H	21.78	217	23.87	10%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0091	3.0675	W	16.94	171	19.02	12%
		H	21.78	224	24.91	14%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0096	3.323	W	16.94	172	20.726	22%
		H	21.78	225	27.1125	24%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0101	3.443	W	16.94	172	21.4656	27%
		H	21.78	229	28.5792	31%

DJI_0091: drone moved 0.64m to the left

DJI_0096: drone moved 1.43m to the left

DJI_0101: drone moved 1.43m to the left and descended 0.9m

As the yaw and pitch angles of the drone increase, the percentage error gradually increases. It is 3 times the percentage error between the most distorted and perpendicular images.

Similar comparisons are made for 5m, 7m and 9.65m

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0088	5	W	16.94	102	18.36	8%
		H	21.78	132	23.76	9%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0074	5.14	W	16.94	100	19	12%
		H	21.78	130	24.7	13%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0076	5.14 (with distortion)	W	16.94	106	20.14	19%
		H	21.78	134	25.46	17%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0097	5.2	W	16.94	107	20.1695	19%
		H	21.78	138	26.013	19%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0102	5.2778	W	16.94	108	20.6604	22%
		H	21.78	136	26.0168	19%

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0089	7	W	16.94	75	18.75	11%
		H	21.78	95	23.75	9%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0093	7.029	W	16.94	72	18.3456	8%
		H	21.78	95	24.206	11%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0098	7.1446	W	16.94	75	19.425	15%
		H	21.78	96	24.864	14%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0103	7.2	W	16.94	76	19.836	17%
		H	21.78	96	25.056	15%

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0078	9.65	W	16.94	54	18.9	12%
		H	21.78	70	24.5	12%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0090	9.65	W	16.94	55	19.25	14%
		H	21.78	72	25.2	16%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0094	9.671	W	16.94	53	18.58	10%
		H	21.78	69	24.19	11%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0099	9.755	W	16.94	57	20.1552	19%
		H	21.78	74	26.1664	20%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0104	9.7968	W	16.94	55	19.5305	15%
		H	21.78	71	25.2121	16%

Conclusion (Problems to handle)

1. Human error when measuring pixel numbers, which can be seen difference % error for the same capturing distance. Using AI to recognize thermal images of defects will be a better option.
2. Minimize error in dimensioning for perpendicular photos.
3. Handle distortion of photos which induce higher % error.

Camera Calibration

10 May 2022

Created by Oscar Siu

Workflow



1. Capture checkerboard images in different angles (>10)
2. Camera calibration -> camera matrix
3. Capture a sample image with known distance and measure real world points (>=9 points)
4. Perspective calibration
5. Obtain GSD for each test point and find minimum GSD

Description:

To find an accurate GSD for a camera, the above workflow has to be done once before actually using it in operation. After the minimum GSD is obtained, the new GSD for different distances of each photo can be calculated:

$$\text{new GSD} = \text{min. GSD} * \text{new dis} / \text{sample dis}$$

The minimum GSD is chosen since it can maximize the accuracy of the calculated dimensions. Since we use a unique GSD for every point in the images, the perpendicular distance is sufficient to obtain a highly accurate result even the object is not exactly in the middle of the images.

Test

Camera used: DJI Mini 2

Noted that the images were resized from 4000x2250 to 1280x720 for faster processing time.

Perspective calibration result

GSD: [0.37699370472167204, 0.44508431178516555, 0.3742397589094155, 0.3617693410237761, 0.32247138546467735, 0.40778272799761806, 0.5314234153625725, 0.4216809291325689, 0.4421218668584465]

Min GSD: 0.32247138546467735 cm/pixel

Verification

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0087	3	W	16.94	54	17.28	2%
		H	21.78	68	21.76	-0.1%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0088	5	W	16.94	33	17.73593	5%
		H	21.78	42	22.573	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0089	7	W	16.94	23	17.30596	2%
		H	21.78	30	22.573	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0090	9.65	W	16.94	17	17.63381	4%
		H	21.78	22	22.82023	5%

The percentage error between calculated dimensions and actual dimension is reduced to 5% maximum, 3% in average. Comparing to an average of 11% error in previous test, the result is much better and accurate.

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0087	3	W	16.94	54	17.28	2%
		H	21.78	68	21.76	-0.1%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0091	3	W	16.94	53	17.09	1%
	3.0675	H	21.78	69	22.25	2%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0096	3	W	16.94	53	17.09098	1%
	3.323	H	21.78	71	22.89547	5%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0101	3	W	16.94	55	17.73593	5%
	3.443	H	21.78	72	23.21794	7%

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0088	5	W	16.94	33	17.73593	5%
		H	21.78	42	22.573	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0092	5	W	16.94	32	17.20	2%
	5.0408	H	21.78	42	22.57	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0097	5	W	16.94	33	17.73593	5%
	5.2	H	21.78	42	22.573	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0102	5	W	16.94	33	17.73593	5%
	5.2778	H	21.78	42	22.573	4%

	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0089	7	W	16.94	23	17.30596	2%
		H	21.78	30	22.573	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0093	7	W	16.94	23	17.30596	2%
	7.029	H	21.78	29	21.82056	0%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0098	7	W	16.94	23	17.30596	2%
	7.1446	H	21.78	30	22.573	4%
	Dis		Actual	pixels	Cal(GSDw)	%error
DJI_0103	7	W	16.94	23	17.30596	2%
	7.2	H	21.78	30	22.573	4%

There is not much difference in percentage error when the object is shifted in the images. The overall percentage error still within 10%.