

Exterior Orientation in a Box

Cost-Effective RTK/IMU-Based Photo Geotagging

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Low-Cost 3D, 12.11.2024



TU WIEN
DEPARTMENT OF GEODESY
AND GEOINFORMATION
RESEARCH DIVISION
PHOTOGRAMMETRY



universität
wien



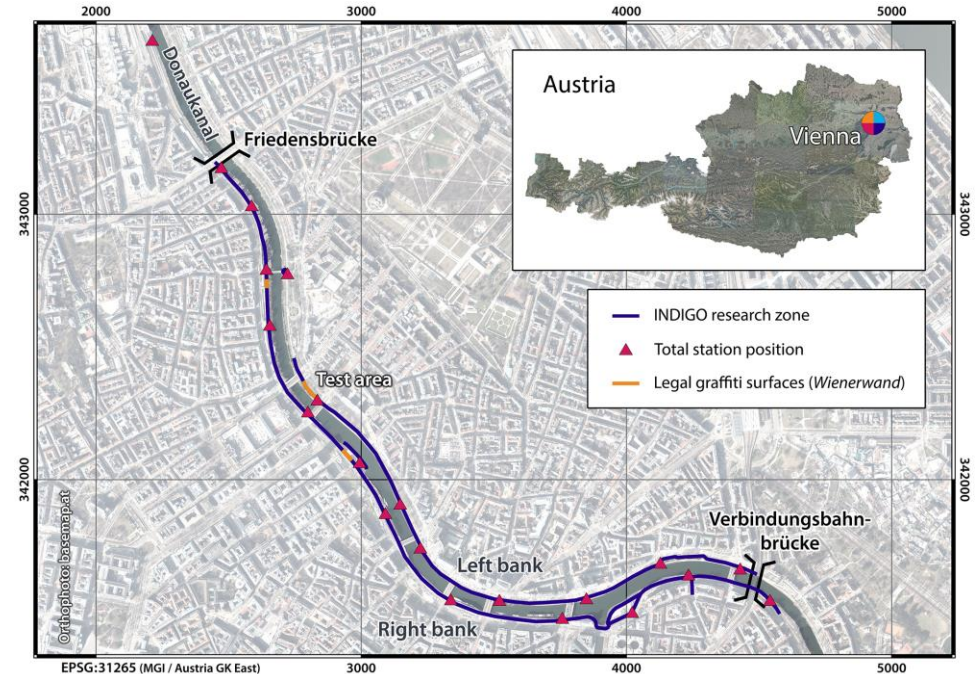
Stadt
Wien

Project INDIGO

Inventory and disseminate graffiti along the Danube canal



~13km of structures with graffiti
2x total coverage image survey
On average 4000/month additional images to track changes.



RTK/IMU Device – Main Components

Built from **Sparkfun & Adafruit open-source components**.
Libraries are provided for all sensors dealing with
communication and settings



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Hot Shoe Port
used for image
synchronisation



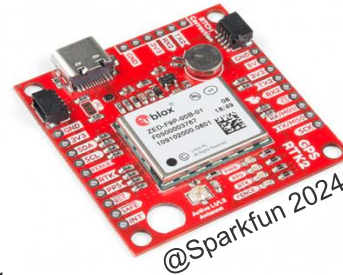
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Ublox ZED-F9P (GNSS receiver)
multi-constellation
multi-band
RTK



Sparkfun Board:
PPS signal
communication port

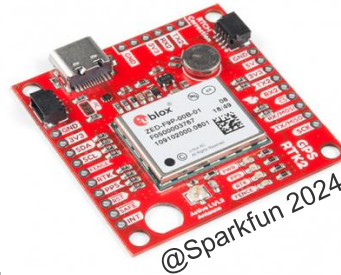
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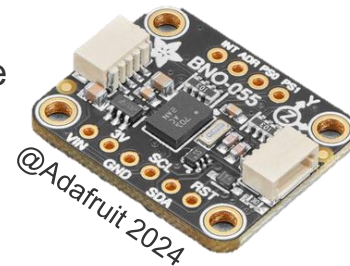


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Sparkfun Board:
PPS signal
communication port

Bosch BNO055 (IMU - 9 DoF)
3-axis 14bit accelerometer
3-axis close-loop 16bit gyroscope
3-axis geomagnetic sensor



Adafruit Board:
communication port

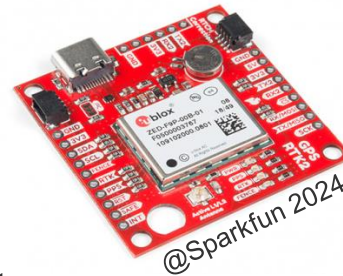
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Sparkfun Board:
PPS signal
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@Sparkfun 2024

ESP32-S2 WROOM

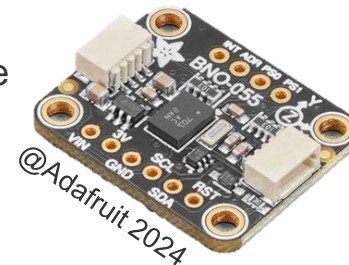
Xtensa® Single-Core 32-bit
(up to 240MHz)
Built-in WIFI



Sparkfun Board:

USB-C also for battery charging
GPIOs, Communication Ports

Bosch BNO055 (IMU - 9 DoF)
3-axis 14bit accelerometer
3-axis close-loop 16bit gyroscope
3-axis geomagnetic sensor



Adafruit Board:
communication port

@Adafruit 2024

RTK/IMU Device – Operation & Firmware



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Time-critical synchronisator

- time frame via GNSS using PPS and Ublox-protocol
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Exterior ORI. processor

- communication with GNSS receiver and the IMU
- IMU calibration



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- communication with NTRIP server via RTCM protocol
- forwards correction data to GNSS receiver

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User interface

- using WIFI connection
- configure WIFI & RTK
- download recorded data

NTRIP-Client

NTRIP CLIENT ACTIVATION ☐ OFF **POSITION** M **RTK STATUS** NO

WiFi Network Client Access Data

This NTRIP Client requires access to an Internet enabled Network!

If access fails, an screenshot will be created ("NTRIP_Client_" with PW "NTRIP")

Address: Save

Password:

NTRIP Caster Settings

Network Name: Save

Port:

Username:

Password:

Send my Position

(Request if your Caster provides VRS (Virtual Reference Station))

Repeat time: ☐ 1 sec. ☐ 2 sec. ☐ 10 sec. ☐ 20 sec. Apply

Restart NTRIP client for changes to take effect. Restart

@Martin Winter 2012

FILE BROWSER Back to Settings	
<input checked="" type="checkbox"/> Deleting Check	1 #4658260
2022819_92328.txt	2 2,482122709,163796193,157408,3,0,1,0,28
2022824_8198.txt	3 6,482122701,163796220,157354,3,0,1,0,28
info.txt	4 10,482122705,163796247,157308,3,0,1,0,28
	5 14,482122709,163796272,157244,3,0,1,0,28
	6 16,482122713,163796284,157251,3,0,1,0,28
	7 18,482122713,163796291,157317,3,0,1,0,27
	8 20,482122713,163796292,157298,3,0,1,0,27
	9 22,482122708,163796294,157239,3,0,1,0,28
	10 24,482122696,163796287,157218,3,0,1,0,28
	11 26,482122682,163796286,157313,3,0,1,0,28
	12 28,482122678,163796276,157622,3,0,1,0,28
	13 30,482122681,163796279,157750,3,0,1,0,28
	14 32,482122689,163796281,157828,3,0,1,0,26
	15 34,482122699,163796290,157830,3,0,1,0,27
	16 36,482122710,163796302,157799,3,0,99,1,27
	17 38,482122712,163796312,157771,3,0,98,1,27
	18 40,482122716,163796321,157752,3,0,96,1,27
	19 42,482122716,163796323,157717,3,0,95,1,28
	20 44,482122721,163796323,157694,3,0,94,1,28
	21 46,482122725,163796316,157709,3,0,92,1,28
	22 48,482122730,163796304,157720,3,0,91,1,28
	23 50,482122737,163796284,157735,3,0,90,1,28
	24 52,482122746,163796266,157752,3,0,88,1,27
	25 54,482122752,163796249,157706,3,0,87,1,27
	26 56,482122757,163796240,157655,3,0,86,1,27
	27 58,482122760,163796235,157597,3,0,85,1,27
	28 60,482122761,163796236,157545,3,0,84,1,27



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Visual feedback

- status LEDs
- display



Data Acquisition

Date: 12th October 2022

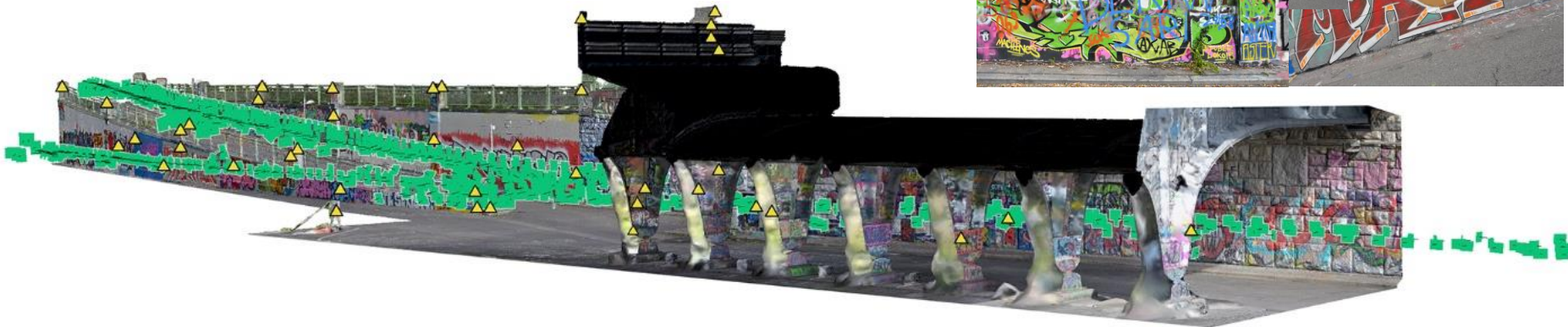
Camera: Nikon Z7 II (45 MP)

Lens: Nikkor Z 20mm f/1.8

Imagery: 777 highly overlapping images in different camera orientations.

GCP: 41 coded targets measured by total station

RTK: VRS mode using EPOSA (Echtzeit-Positionierung-Austria, Eng. Real-time positioning Austria) with a mounting point that uses GPS, GLONASS, Galileo and BDS



Post-Processing

Reference Data

41 Coded targets:

4 stations using Leica TS16

Control Points from city of Vienna

Std. Dev. Residuals: XY 9 mm, Z 4mm

Bundle block:

40k interest points / 4k tie points

Targets indicated 1085 times

Self-calibration of IOR

Georeferencing accuracy metric	Value
RMSE _x	5.3 mm
RMSE _y	4.0 mm
RMSE _{xy} (total planimetric accuracy)	6.6 mm
RMSE _z	5.8 mm
RMSE _{xyz} (total 3D positional accuracy)	8.8 mm

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RTK/IMU Device

Synchronise images with log file:

- Equal nr. – direct assignment
- Unequal nr. - correlation of images(camera time) and log signals (GNSS time). Happens rarely

Coordinate transformations:

- ZED-F9P cannot use correction data(parameter, NTv2 grids)
- Sufficient coordinate transformations are not possible on main processor.

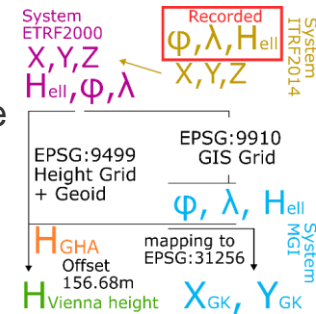
Rotation transformation:

Quaternions logged from IMU

Transform to Device's CRS (X forward, Z up)

Corrections: Magnetic declination and grid convergence

Post processing software to perform all necessary operations.



RTK Solution Status – Classification



Solution loss of FIX expected under/near bridge.

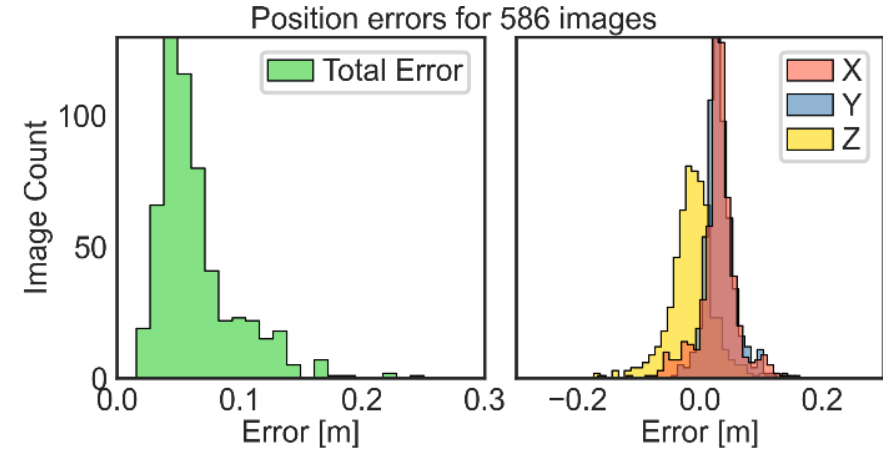
Non expected solution loss in open area:

- shadowing from User
- non-zenith pointing antenna
(elec. characteristics of helical antenna)

Solution Flag	Images	Recorded Position Accuracy	Total Error to Reference Block
No Solution	46	0.12 m – 1.00 m	0.33 m – 13.00 m
Floating	133	0.01 m – 1.00 m	0.05 m – 21.00 m
Fix	598	0.01 m – 0.03 m	0.02 m – 0.53 m
Class	Images	Recorded Position Accuracy	Total Error to Reference Block
1 st order quality	586	0.01 m	0.02 – 0.46 m only 14 >15 cm
All others	191	0.01 m – 1.00 m	0.05 m – 21.00 m

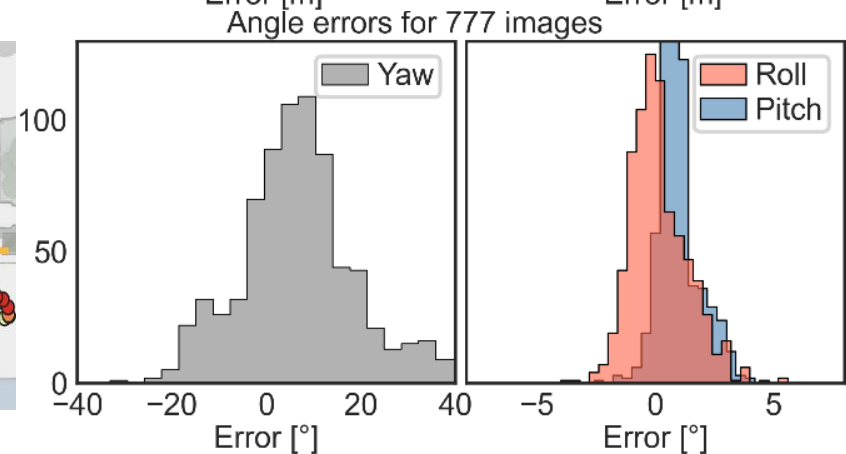
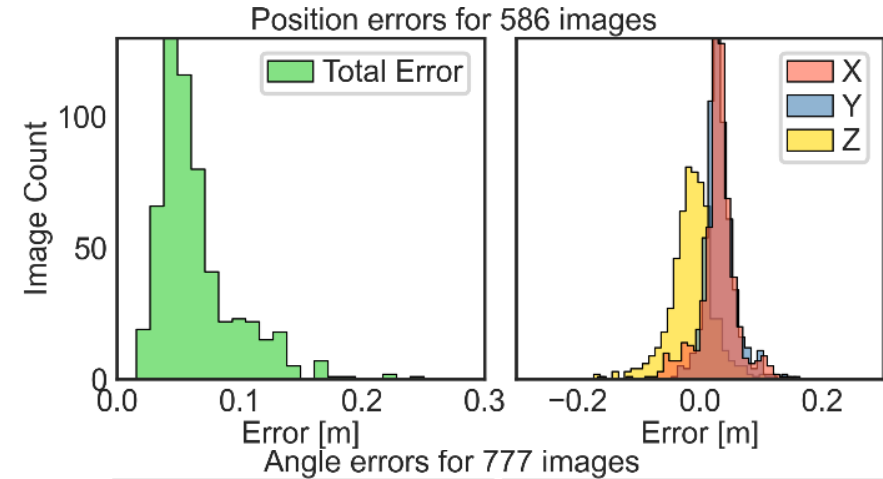
Exterior Orientation vs. Reference Block

Error	X [cm]	Y [cm]	Z [cm]	Total [cm]	Roll [°]	Pitch [°]	Yaw [°]
Mean	2.9	2.8	-1.9	6.5	0.17	0.73	2.93
Median	3.0	2.5	-1.8	5.4	0.01	0.59	1.79
St. Dev.	3.1	2.7	4.4	3.9	1.22	0.81	15.3
RMSE	4.3	3.9	4.8	7.6	1.23	1.09	15.6



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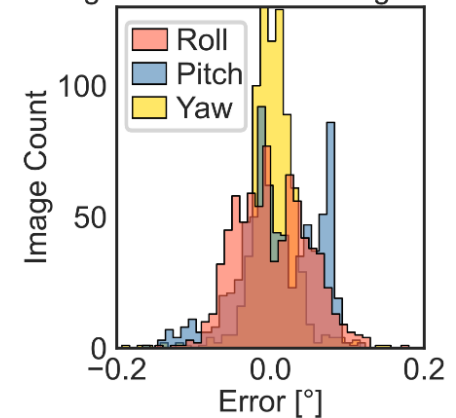
Bundle Block Adjustment with RTK-GNSS Positions

- First order GNSS positions are used as block constraints
- No additional reference data
- Camera Calibration on the job
- Antenna Mounting calibration

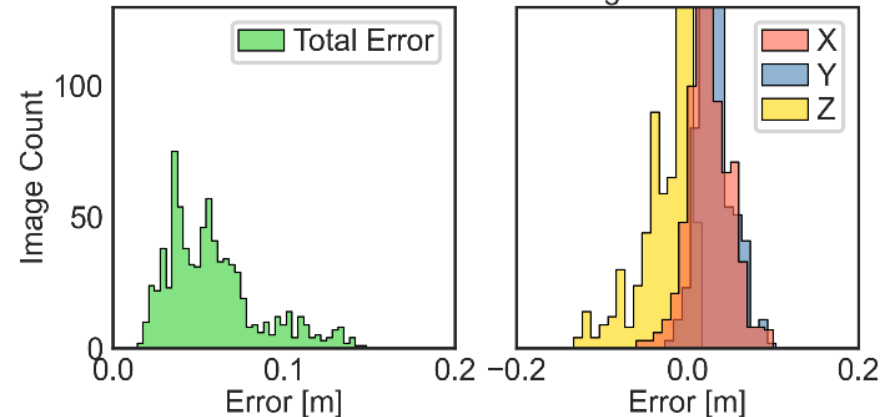
No post adjustment/filtering applied

Error	X	Y	Z	Total	Roll	Pitch	Yaw
	[cm]			[cm]	[millidegree]		
Mean	2.4	2.9	-2.9	5.8	3	0	5
Median	2.3	2.6	-1.6	5.3	3	0	4
St. Dev.	2.4	1.9	3.0	2.7	47	67	35
RMSE	3.4	3.5	4.2	6.4	47	67	35

Angle errors for 777 images



Position errors for 777 images



Bundle Block Adjustment with RTK-GNSS Positions

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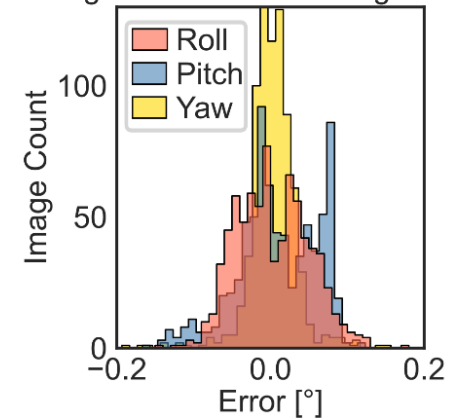
Accuracy on the object

Targets: Reference to Estimated
RMSE of differences:

Total: 31 cm

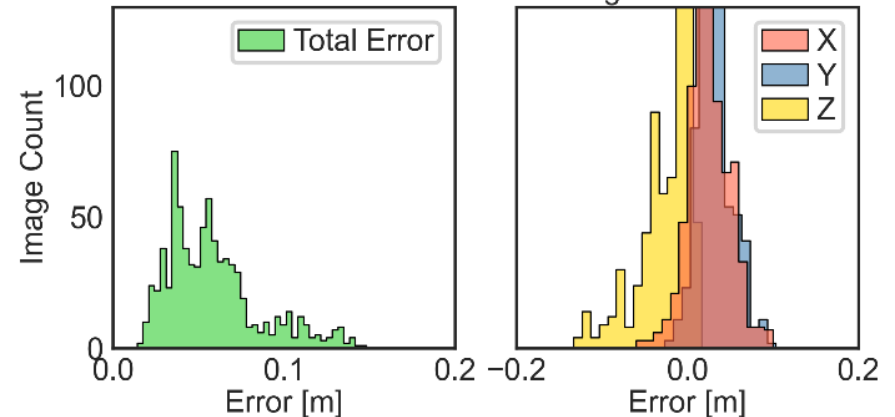
X: 2.5 cm, Y: 8.5 cm, Z: 4.0 cm

Angle errors for 777 images



Error	X	Y	Z	Total	Roll	Pitch	Yaw
	[cm]			[cm]	[millidegree]		
Mean	2.4	2.9	-2.9	5.8	3	0	5
Median	2.3	2.6	-1.6	5.3	3	0	4
St. Dev.	2.4	1.9	3.0	2.7	47	67	35
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Position errors for 777 images

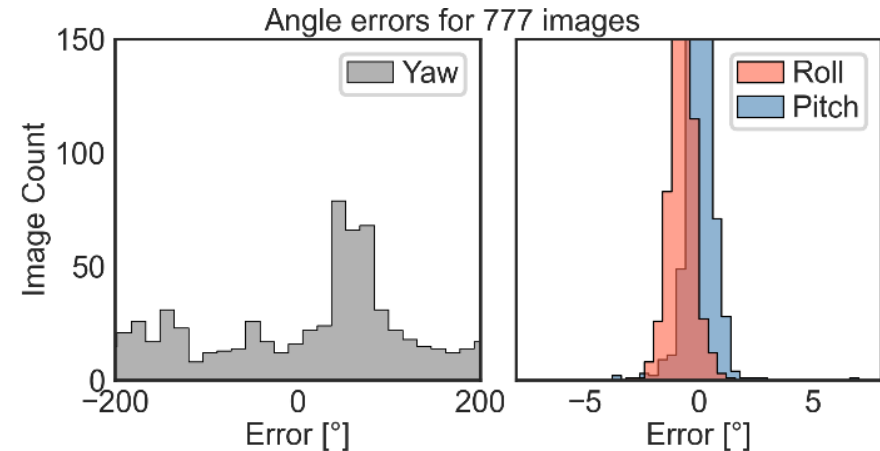


Nikon Angles

IMU of modern cameras store angles in manufacturer-specific Exif Makernote tags

Needed manipulation depending on the rotation of the camera (Exif Orientation tag, ID 274).
Did not find any rotation notation that would have solved that.

Error [°]	Mean	Median	St.dev	RMSE	Min	Max
Roll	-0.7	-0.7	0.5	0.9	-2.8	1.2
Pitch	-0.2	-0.1	0.7	0.7	-3.8	6.5
Yaw	-15.6	-33.5	123.5	124.5	-259.6	350.5



Discussion

Position up to an accuracy of ~6 cm with a **precision of ~3 cm**. Complete EXT. ORI. suffers from magnetometer disturbances.

INDIGO's incremental SfM workflow:

Positions can be used to estimate a temporary bundle block to constrain object space to search for existing features of older images

Low cost: Late 2022 the total cost of the components and the 3D printed case was about € 500

Identified disadvantages:

- additional mass on long duration sessions
- camera does not provide sync signal in silent mode or when using interval priority

