Photogrammetric Accuracy and Modeling of Rolling Shutter Cameras

Jonas Vautherin, Simon Rutishauser,
Klaus Schneider-Zapp, Hon Fai Choi,
Venera Chovancova, Alexis Glass,
Christoph Strecha

PIX4D
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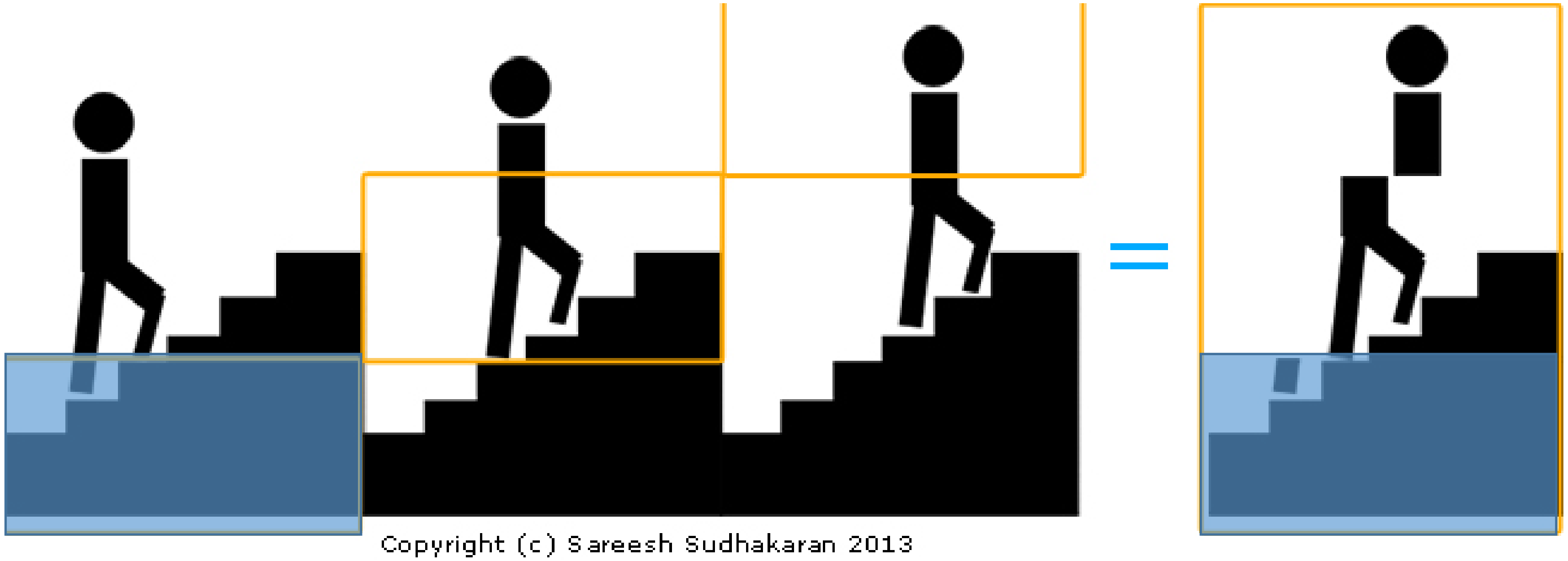
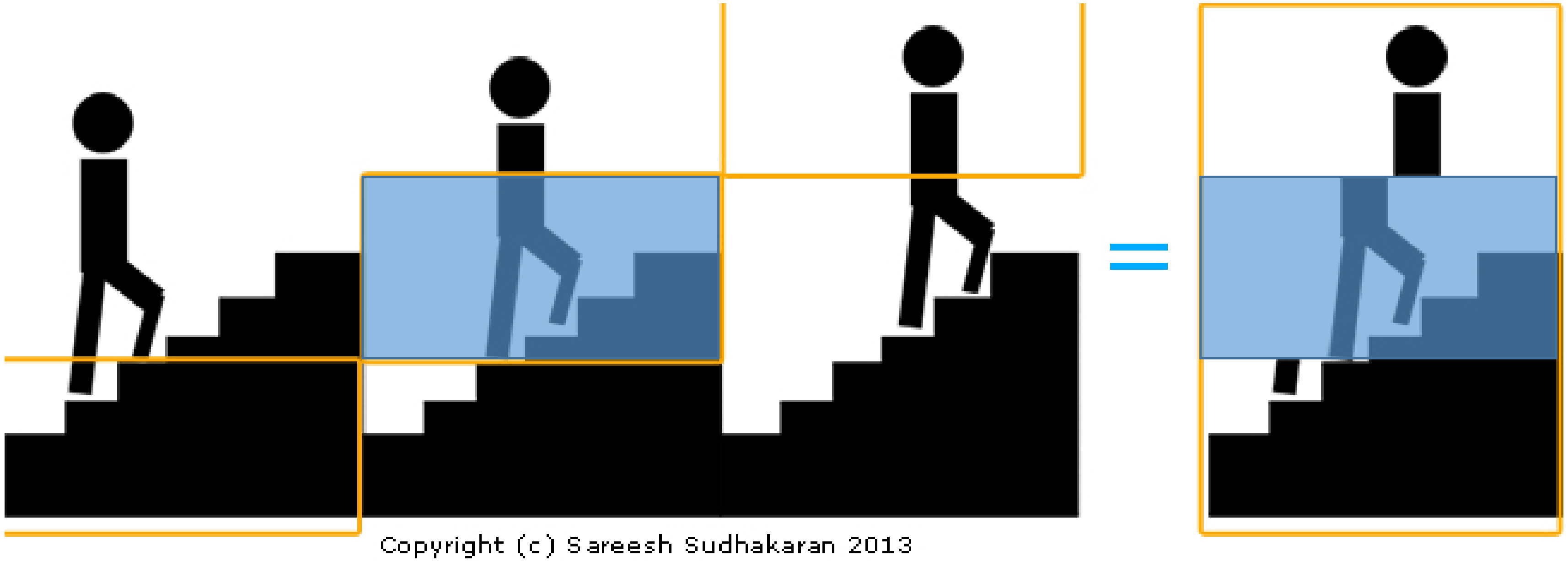
Rolling Shutter



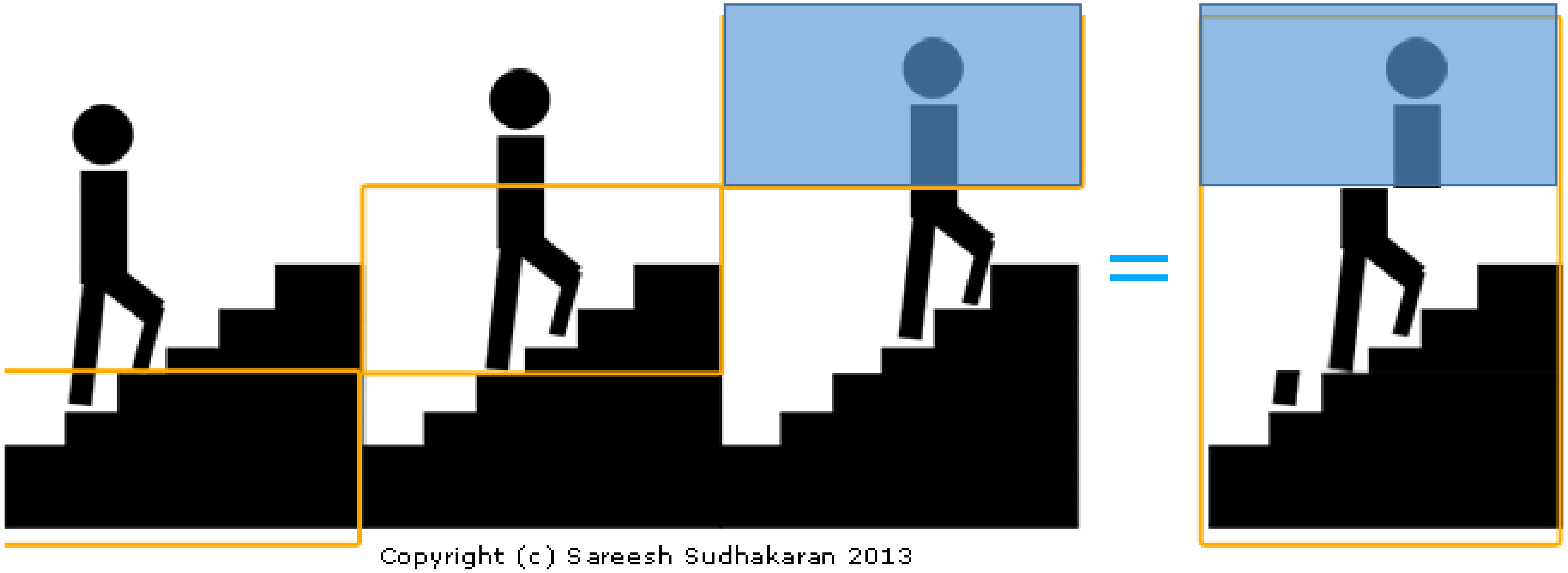
1. Read 1st “line”

Rolling Shutter



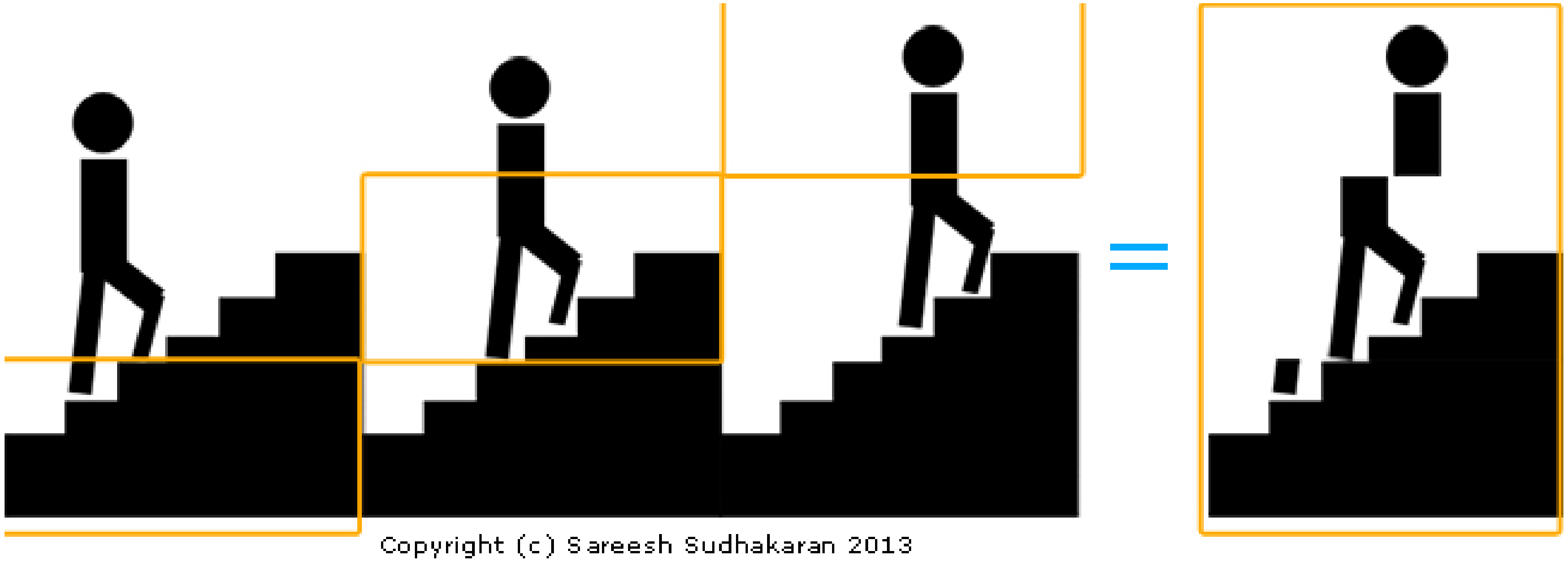
1. Read 1st "line"   2. Read 2nd "line"

Rolling Shutter



1. Read 1st "line" 2. Read 2nd "line" 3. Read 3rd "line"

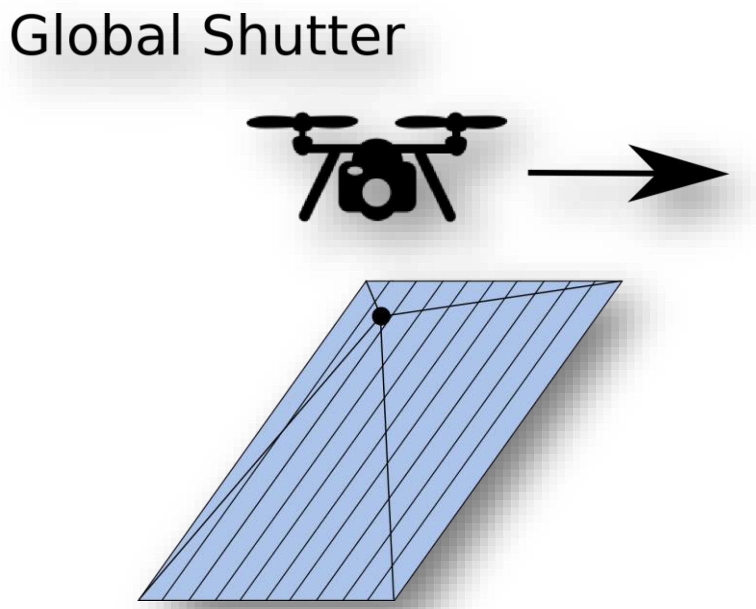
Rolling Shutter



“Rolling shutter effect”

Rolling Shutter

Rolling Shutter & UAVs



$$x = \pi[R \mid -Rc]X$$

π = internal parameters

R = Rotation matrix

c = camera center

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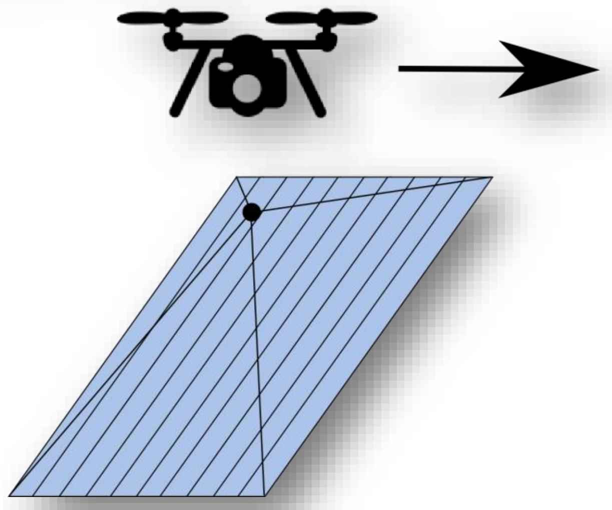
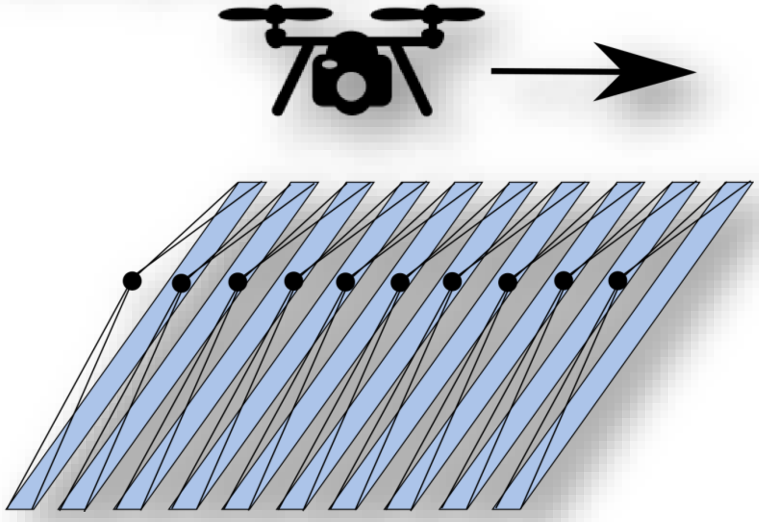
Rolling Shutter & UAVs

Global Shutter



$$x = \pi[R \mid -Rc]X$$

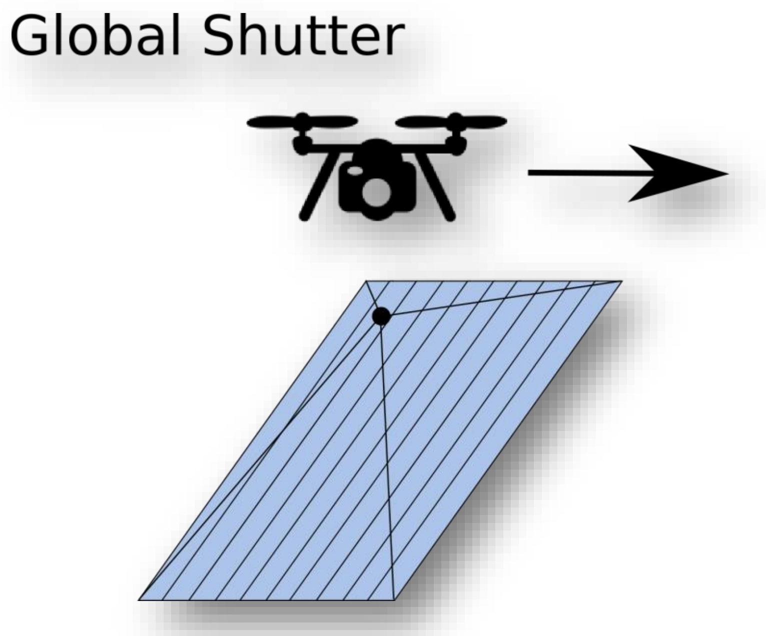
Rolling Shutter



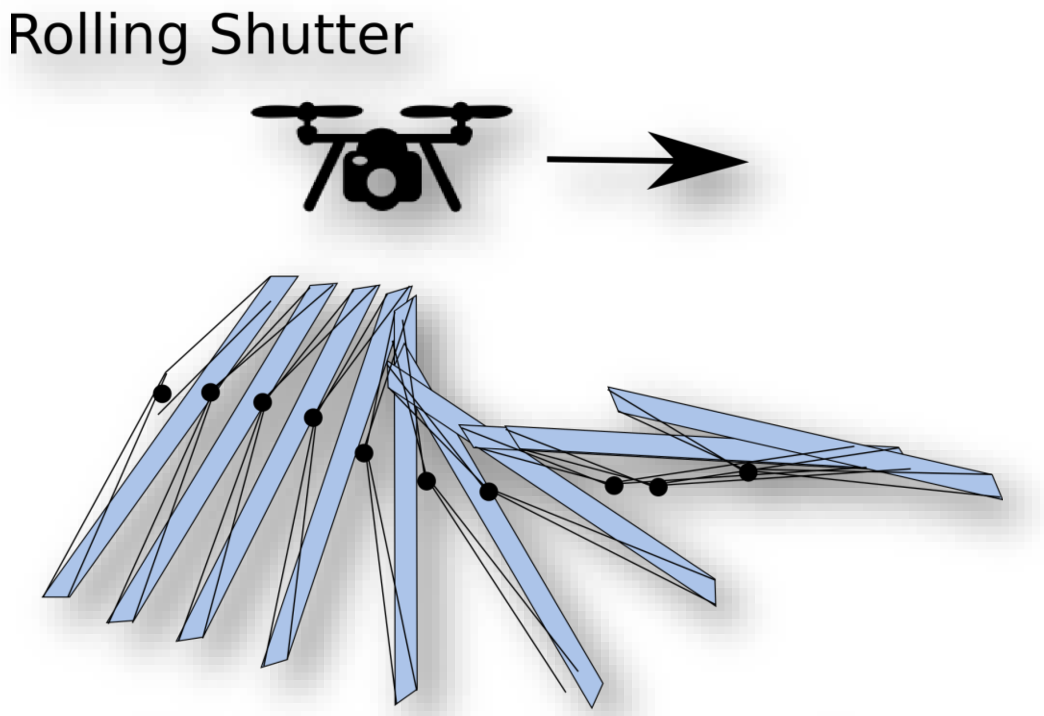
Linear motion: camera center depends on time

$$x = \pi[R \mid -Rc(t)]X$$

Rolling Shutter & UAVs



$$x = \pi[R \mid -Rc]X$$

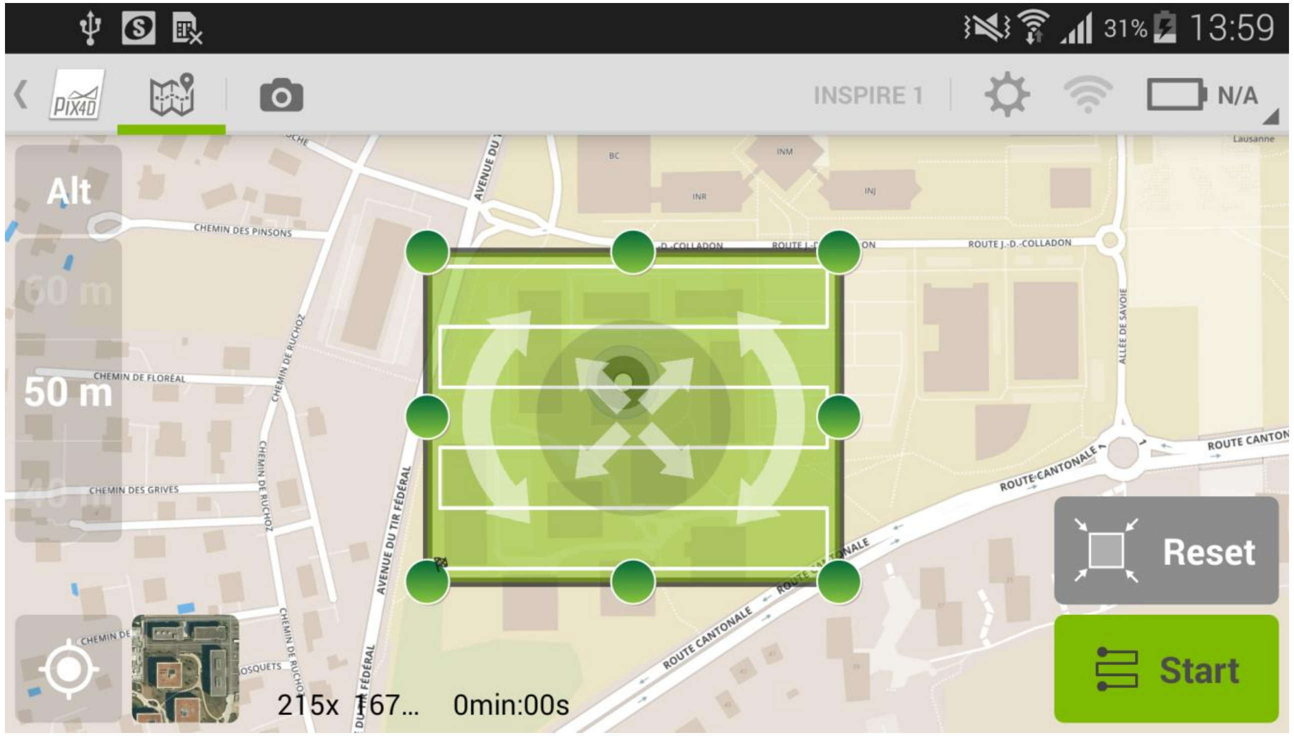


Arbitrary motion: camera center and rotation depend on time

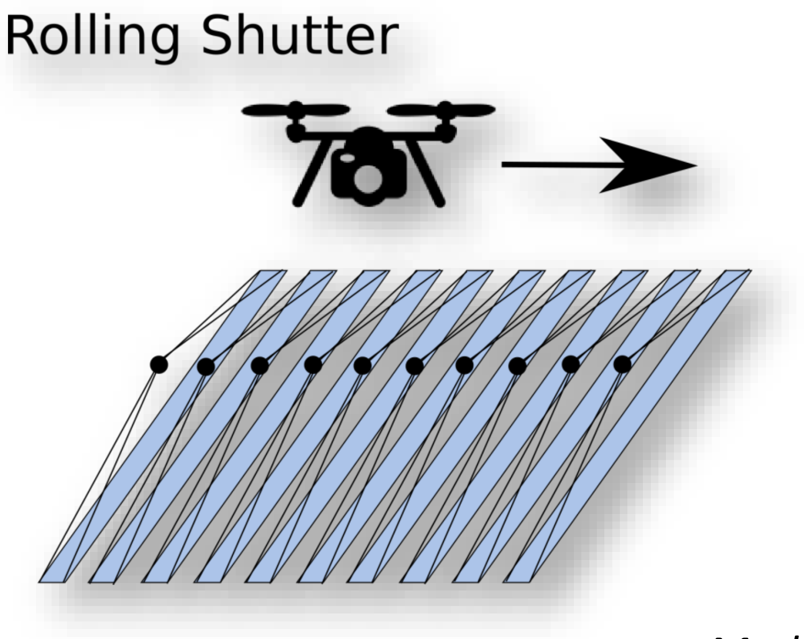
$$x = \pi[R(t) \mid -R(t)c(t)]X$$

Simplified Model

- We control the flight plan
- Gimbal + rubber correct for vibrations



Simplified Model



$$x = \pi[R \mid -Rc(t)]X$$

(9 external parameters per image)

Modeling the rolling shutter effect is not new: Ait-Aider et. al. in 2006: "Simultaneous object pose and velocity computation using a single view from a rolling shutter camera"

Experimental Setup

- Multiple flights at different speeds above Innovation Park:

Drone	Camera	Shutter type	Lens	Field of view []	Speeds [m/s]
P2V+	FC200	Rolling	Fisheye	110/80	1, 4, 8
Inspire 1	FC300X	Rolling	Perspective	85/70	1, 4, 8
eBee	Canon S110	Global	Perspective	71/56	8-13

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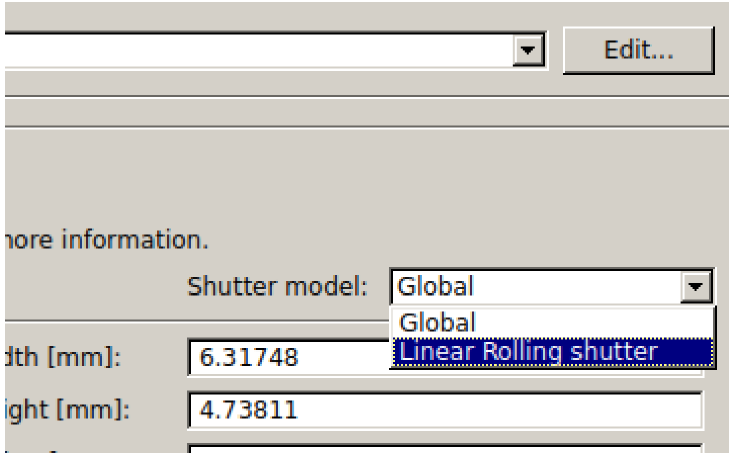
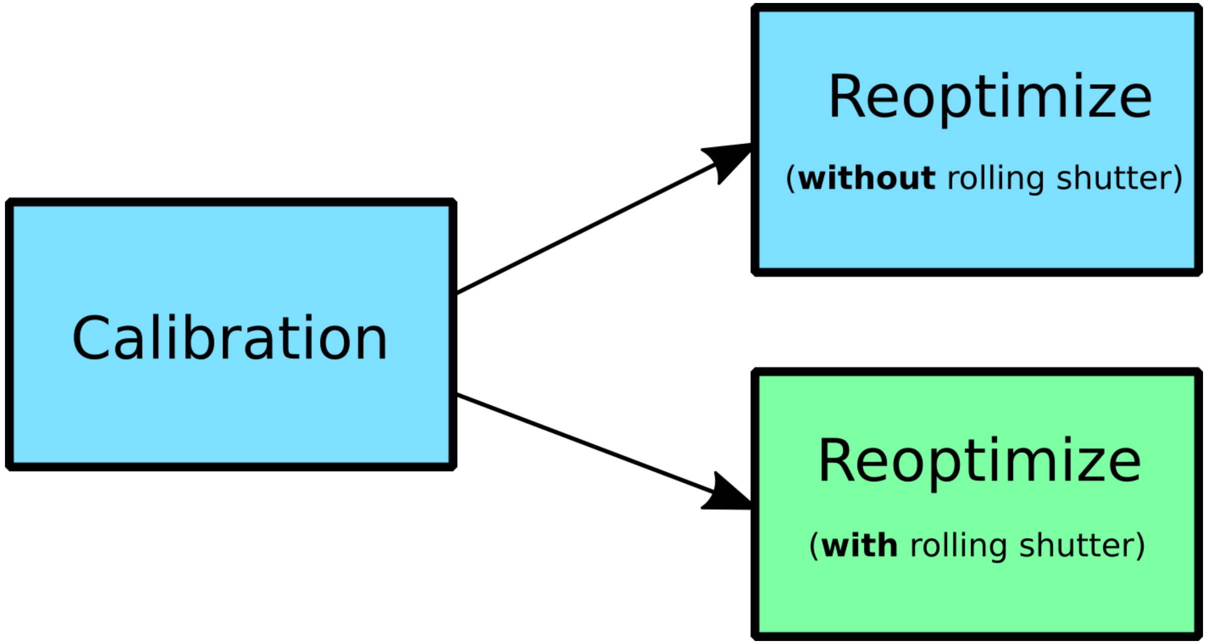
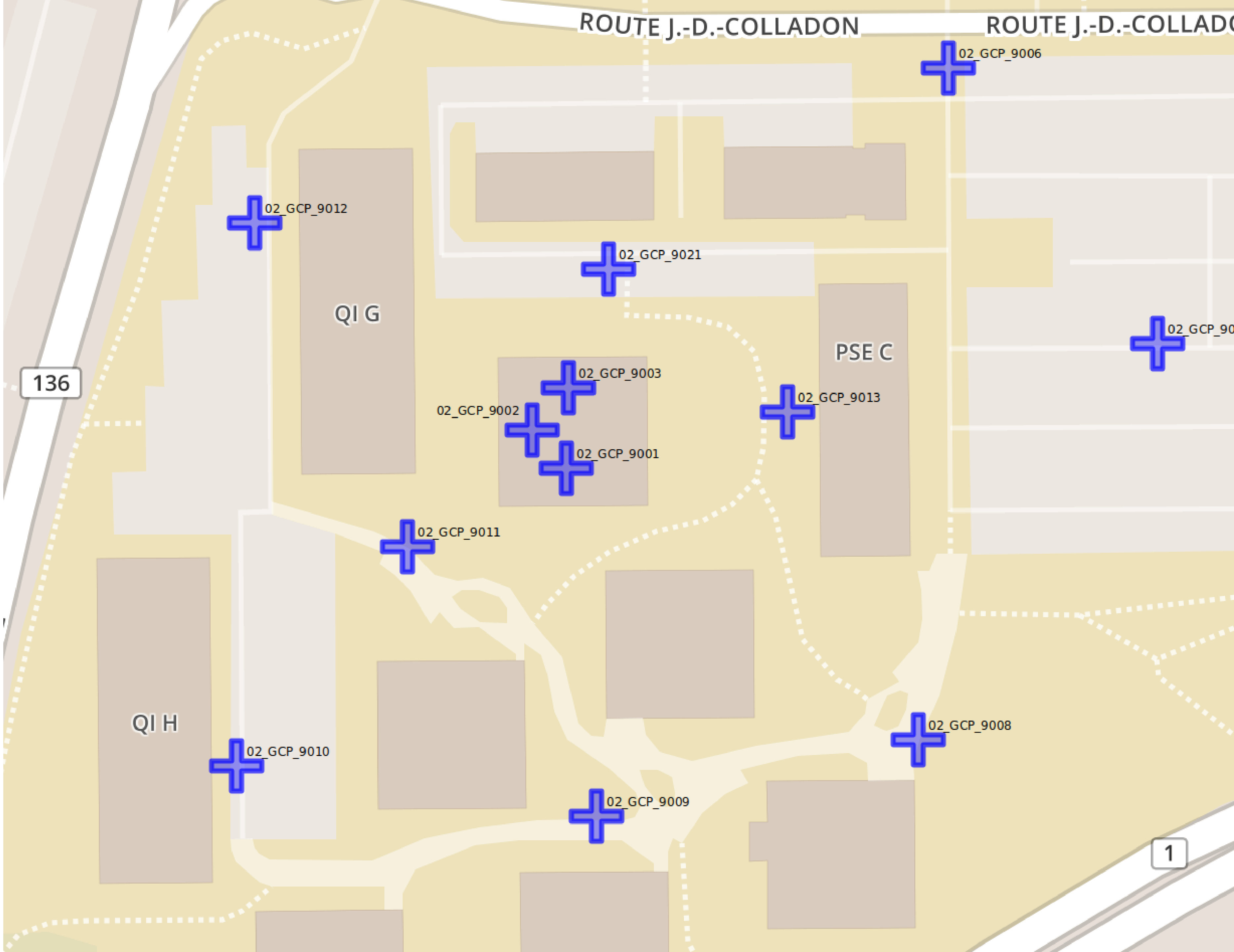
Processing





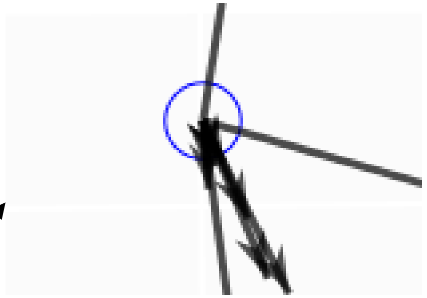
Output: displacement vector during the readout

Test Site

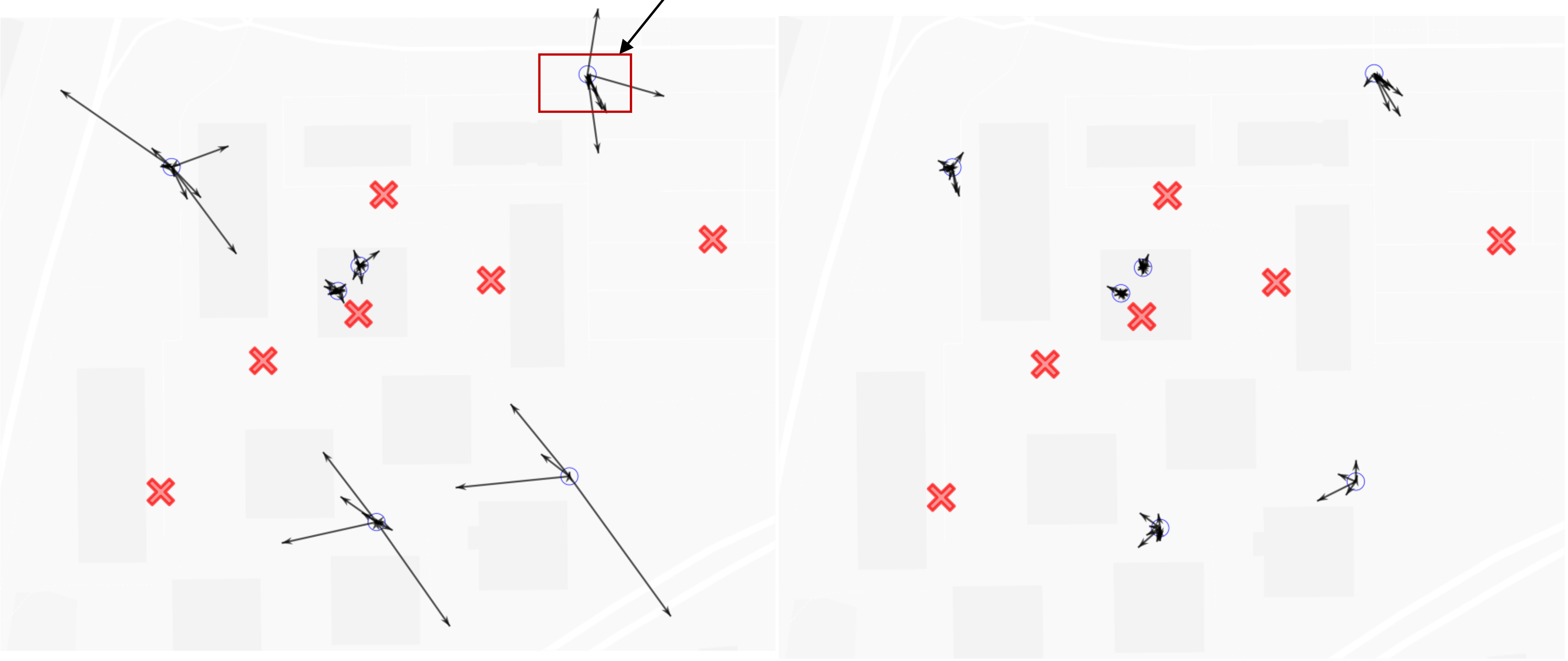


ROUTE J.-D.-COLLADON
ROUTE J.-D.-COLLADO
02_GCP_9006
02_GCP_9012
02_GCP_9021
QI G
PSE C
02_GCP_90
136
02_GCP_9003
02_GCP_9013
02_GCP_9002
02_GCP_9001
02_GCP_9011
QI H
02_GCP_9010
02_GCP_9008
02_GCP_9009
1

Accuracy

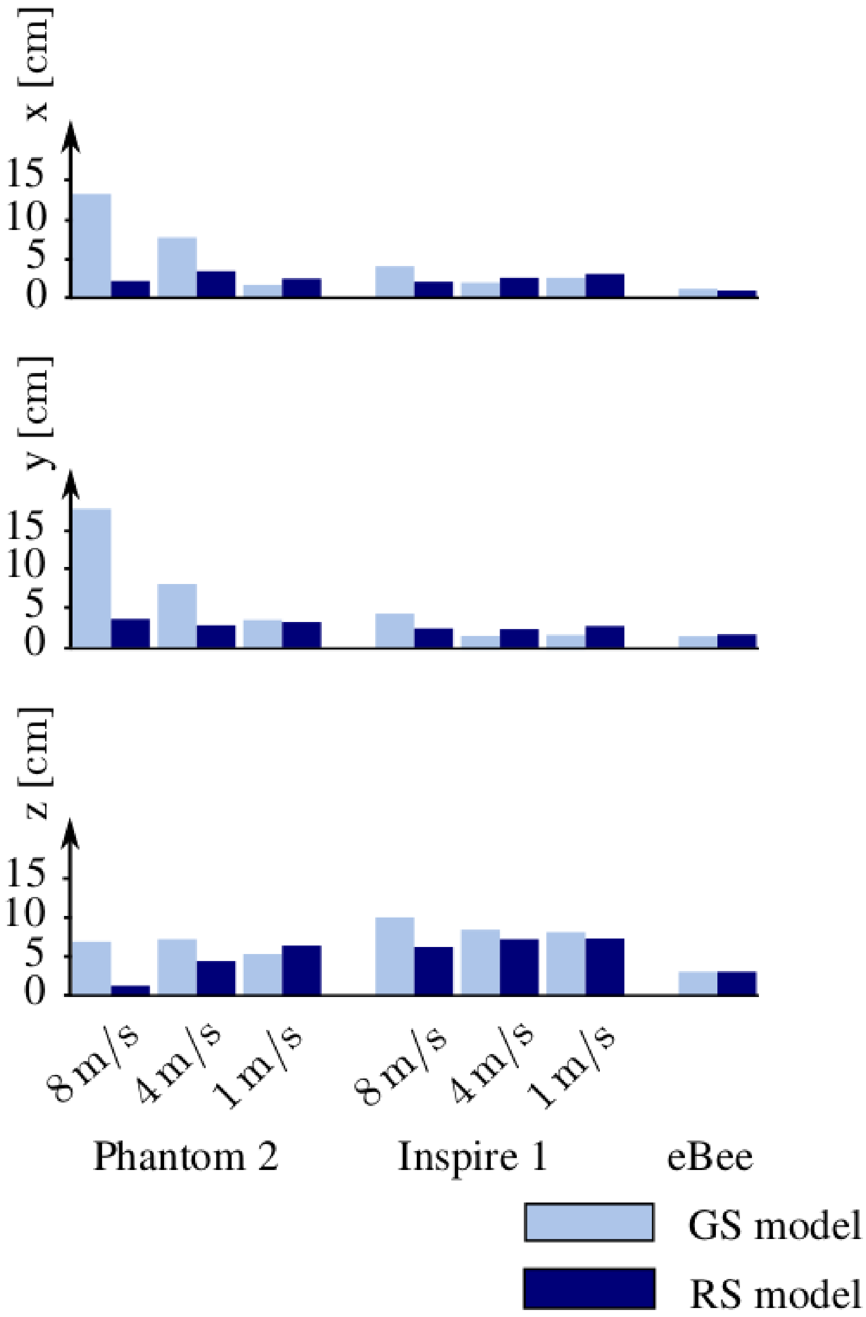


GSD: ~2.8 cm



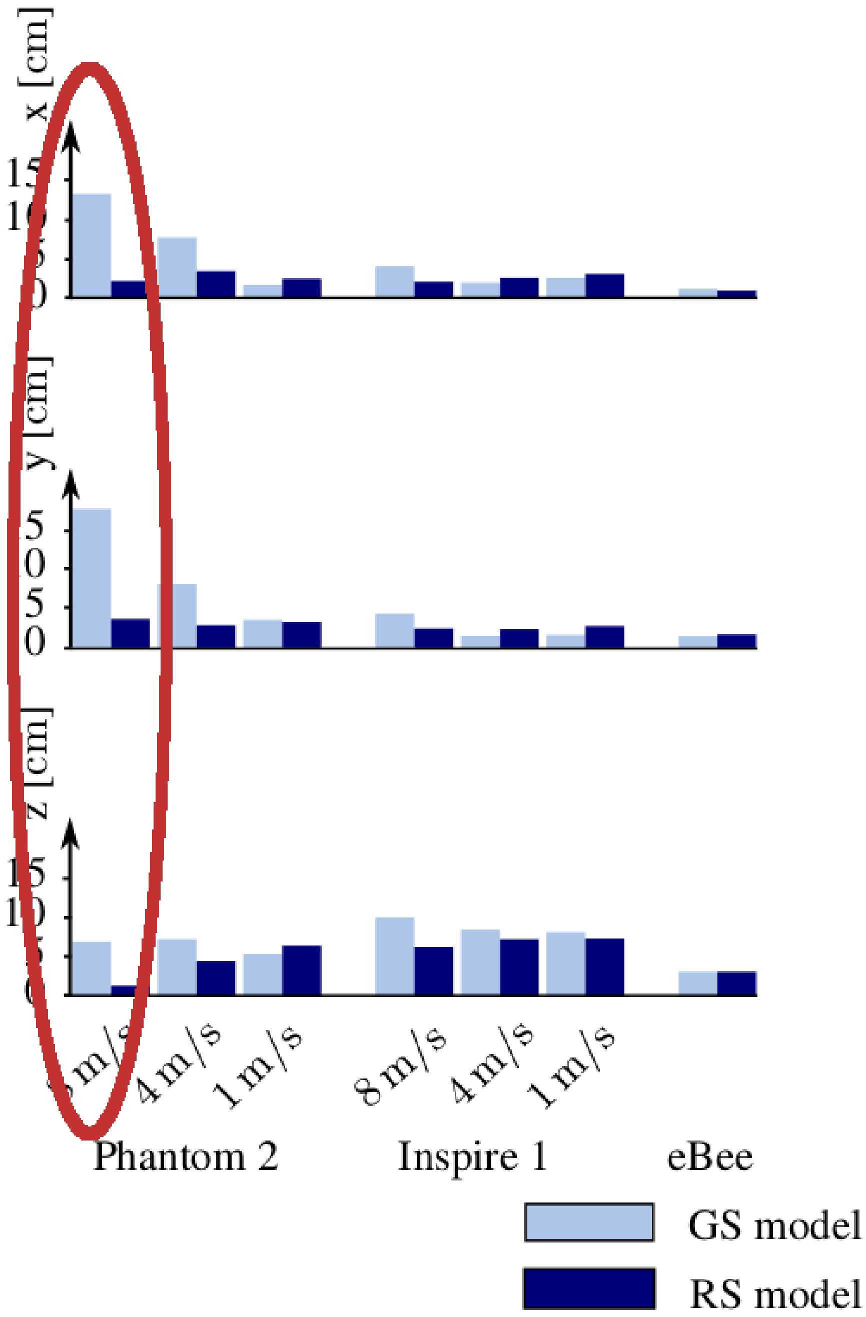
Global shutter model Rolling shutter model

Accuracy



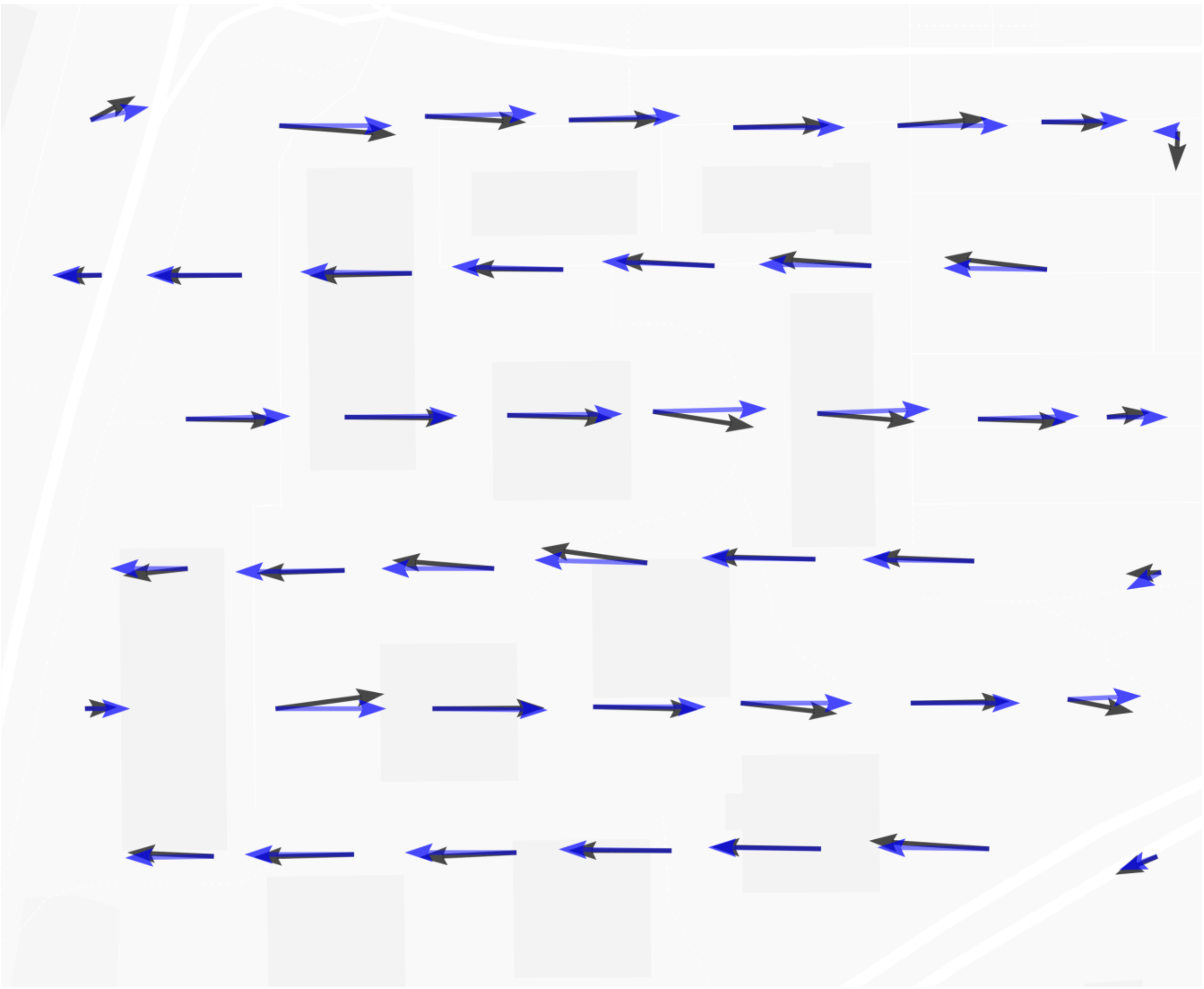
x [cm]
15
10
5
0
y [cm]
15
10
5
0
z [cm]
15
10
5
0
8 m/s
4 m/s
1 m/s
8 m/s
4 m/s
1 m/s
Phantom 2
Inspire 1
eBee
GS model
RS model

Accuracy



x [cm]
15
10
5
0
y [cm]
15
10
5
0
z [cm]
15
10
5
0
8 m/s
4 m/s
1 m/s
8 m/s
4 m/s
1 m/s
Phantom 2
Inspire 1
eBee
GS model
RS model

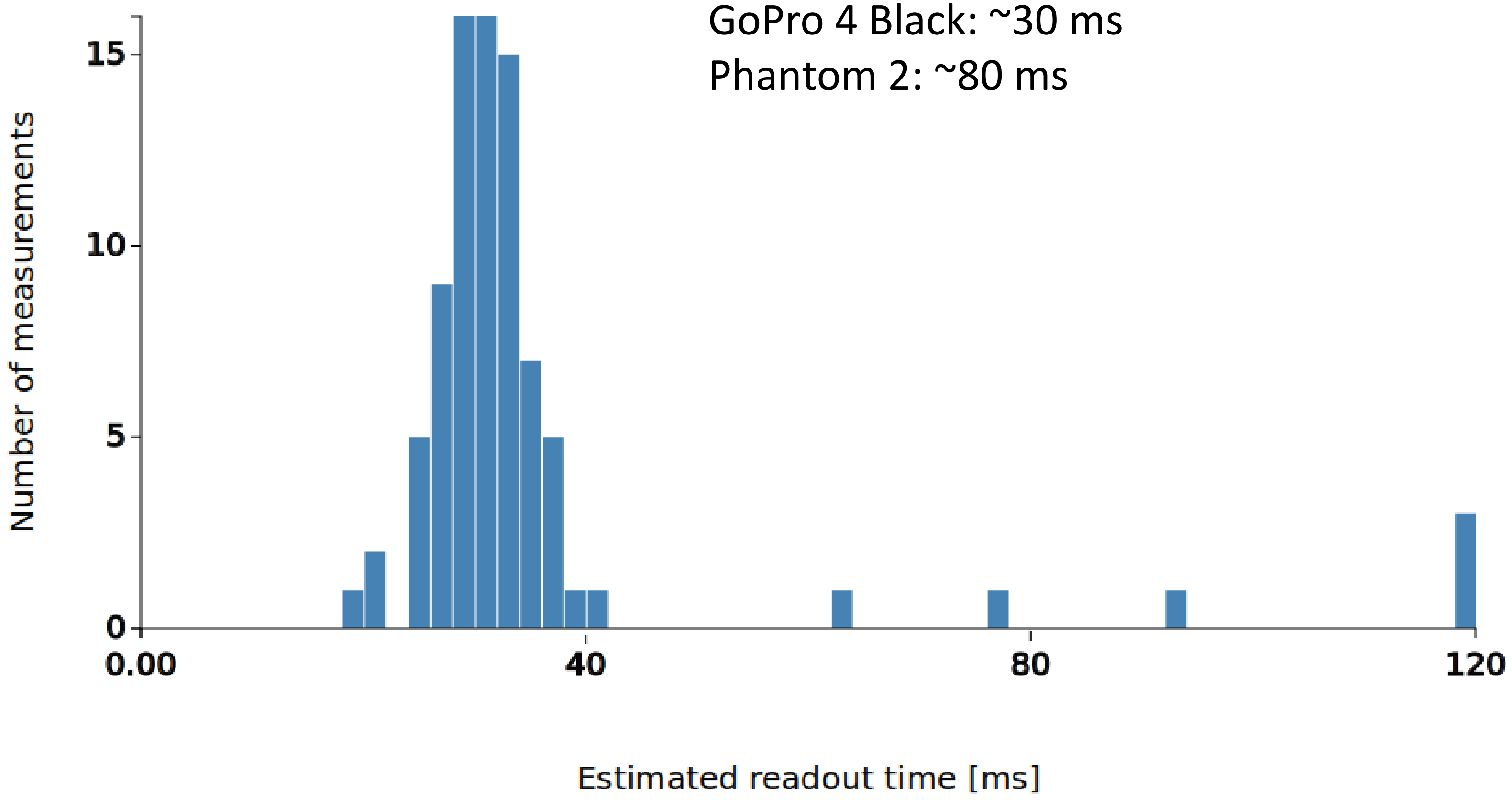
Motion Estimation From RS



Blue: From drone’s telemetry
Black: Rolling Shutter model

Readout time estimation

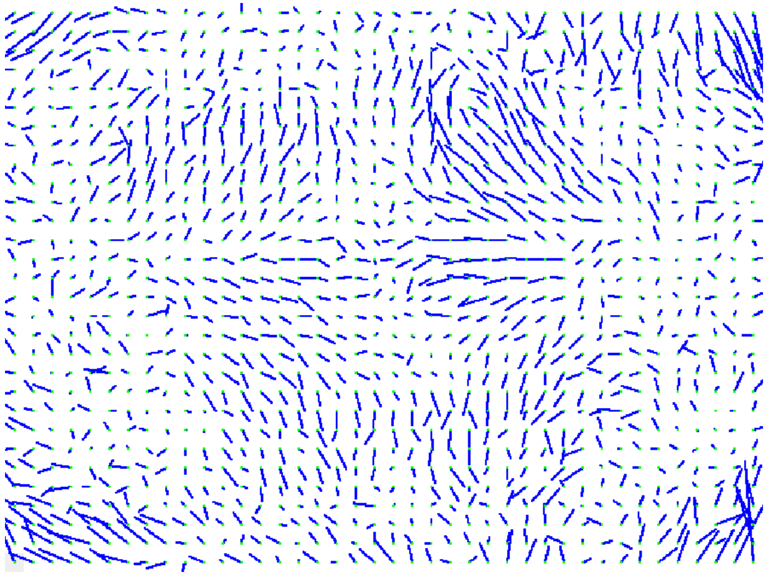
Inspire 1 (this graph): ~30 ms
GoPro 4 Black: ~30 ms
Phantom 2: ~80 ms



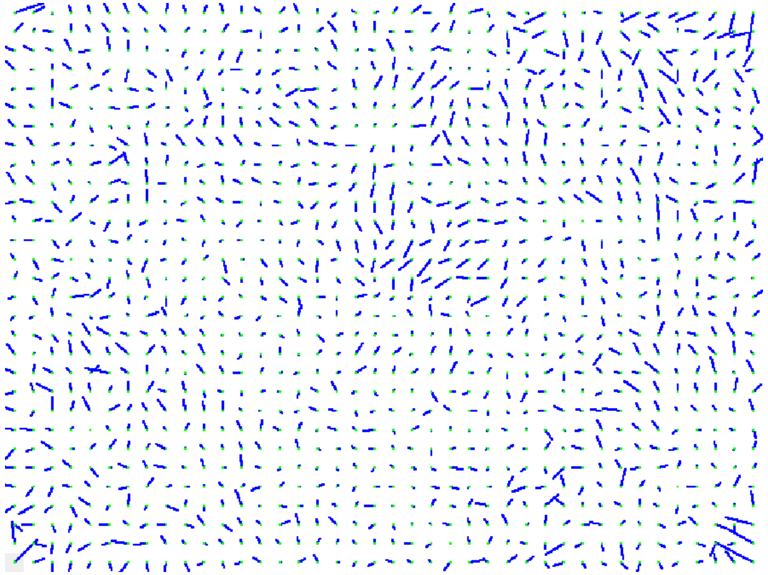
Reprojection Error

Average reprojection error of all automatic tie points

P2V+ at 8 m/s



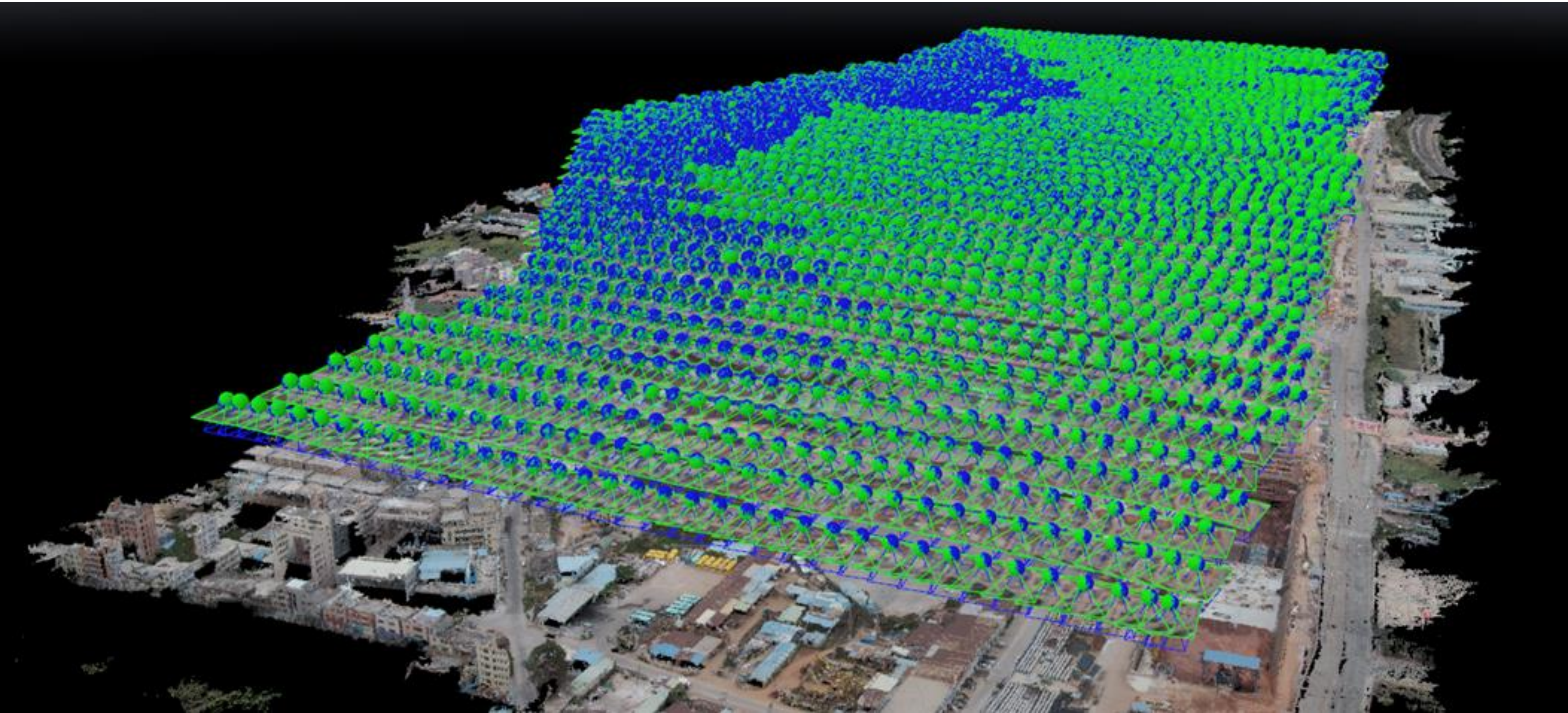
Standard fisheye model



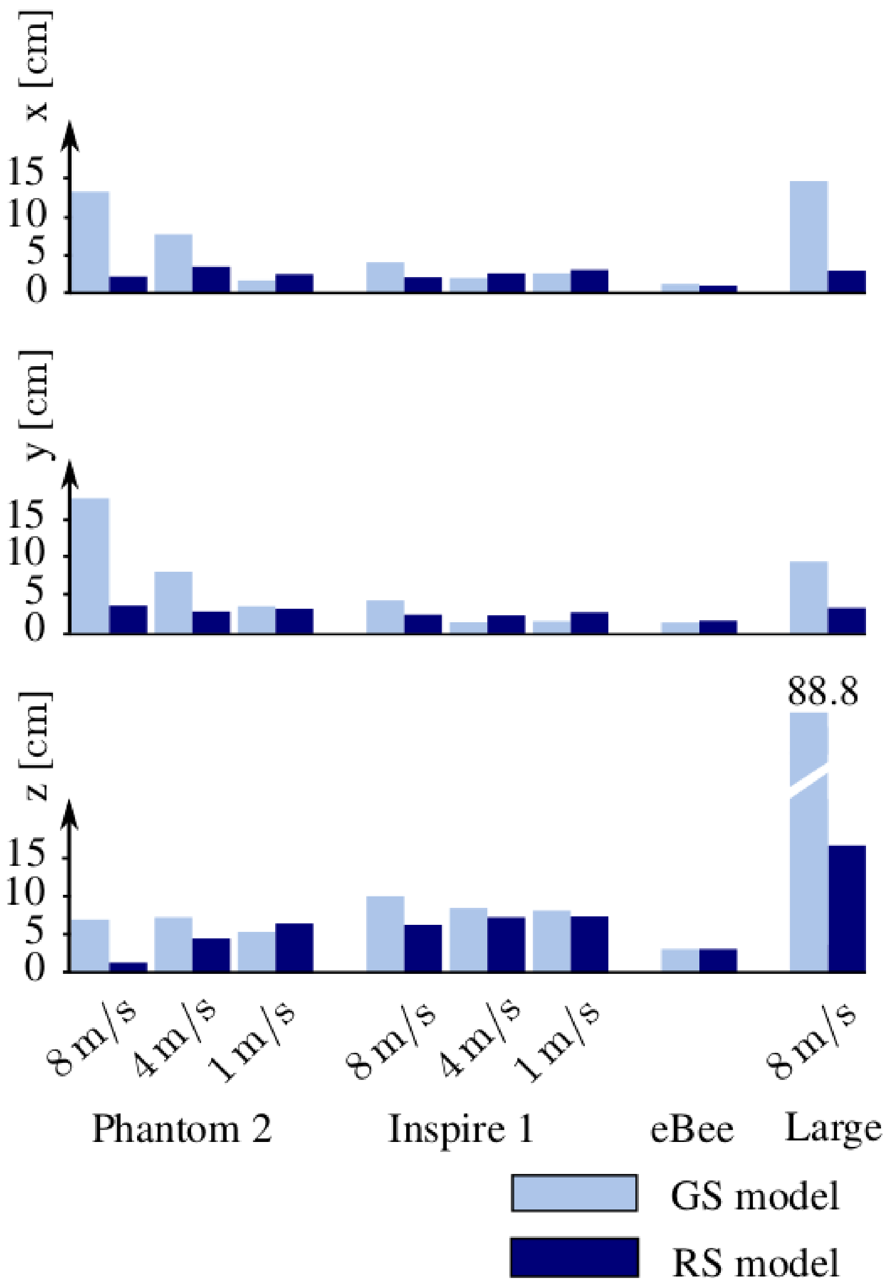
Rolling shutter model

Large Dataset

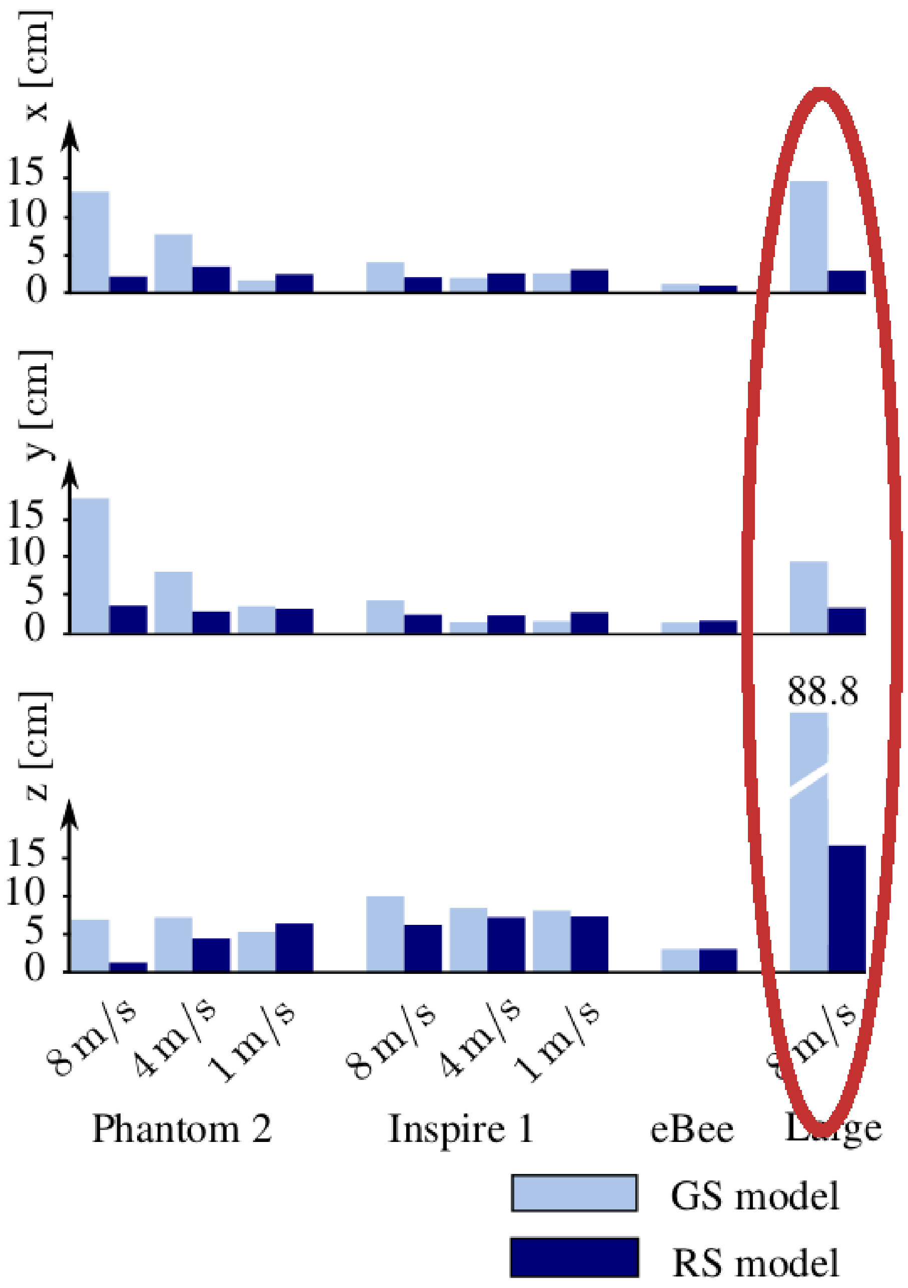
Large Dataset



Large Datase



Large Datase



Conclusion

- Rolling shutter effect can be observed in real-life situations
- Simple linear model + flight plan = better accuracy
- Improved usability for consumer drones
- Speed can be estimated based on images only!

Acknowledgements

- Many thanks to senseFly for the eXom and eBee datasets for our tests.

senseFly
a Parrot company

PIX4D
simply powerful

Thank You!

Accuracy: some numbers

GSD: ~2.8 cm

Camera model	Speed [m/s]	Reproj error [px]	RMS X [cm]	RMS Y [cm]	RMS Z [cm]
P2V+ P2V+ RS	8	0.24 0.23	13.5 2.3	17.9 3.7	7.1 1.4
P2V+ P2V+ RS	4	0.24 0.24	7.9 3.6	8.2 2.9	7.4 4.6
P2V+ P2V+ RS	1	0.24 0.24	1.8 2.6	3.6 3.3	5.5 6.6
Inspire 1 Inspire 1 RS	8	0.28 0.19	4.2 2.2	4.4 2.5	10.2 6.4
eBee eBee RS	8-13	0.23 0.23	1.3 1.1	1.5 1.7	3.2 3.2
Big dataset Big dataset RS	8	0.16 0.15	14.9 3.1	9.5 3.4	88.8 16.9

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