ABC Department

Department of Architecture, Built environment, Construction engineering

POLITECNICO DI MILANO

CAN WE USE LOW-COST 360 DEGREE CAMERAS TO CREATE ACCURATE 3D MODELS?

Luigi Barazzetti,

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Consumer-grade cameras able to capture 360 photos and videos are becoming more popular for the opportunity to look in any direction, exploiting immersive visualization with virtual reality headsets

360 camera	Average Price in February 2018 (euro)
Samsung Gear 360	90
Garmin VIRB 360	800
Insta 360 Air Voor	140
Nikon KeyMission 360	350
Xiaomi Mijia Mi Sphere 360	220
LG 360	150
360FLY	750
Samsung New Gear 360	300
Ricoh Theta V	430
Ricoh THETA S	350
GoXtreme Dome 360	90
Ssstar	100
Sansnail V1	65
YI VR 360	400
Motorola Moto 360	290
Gopro Odyssey	12,200
Videostich Orah 4i	2,900
Gopro Omni	4,000
Nokia OZO	49,000
Sphericam 2	1,350
Insta360 Pro	3,600

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CAMERAS > BEST PICKS

Best 360 Cameras 2018

by MIKE PROSPERO Apr 19, 2018, 8:50 AM

Reviews | Consumer Electronics | Digital Camcorders

The Best 360 Cameras of 2018

Tiny video cameras with multiple ultra-wide lenses capture the entire world around you—all 360 degrees of it. Here's how the most popular models stack up in our testing.

By Jim Fisher May 30, 2018 11:04AM EST

48 SHARES

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Product	Samsung Gear 360 (2017)	GoPro Fusion	Kodak Pixpro SP360 4K	Nikon KeyMission 360	Ricoh Theta SC	Ricoh Theta V	Rylo	Vuze VR Camera	YI 360 VR Camera
	$102.00 Amazon	Best Price Amazon	$339.00 Amazon	$496.95 Amazon	$199.00 Amazon	$429.95 MSRP	$499.00 MSRP	$799.00 Amazon	$399.99 Amazon

Compare the top 360 cameras available now

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Best 360-degree cameras out now and on the way

The top 360-degree cameras to check out

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Tuesday
March 27, 2018

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Photo: Geoffrey Morrison

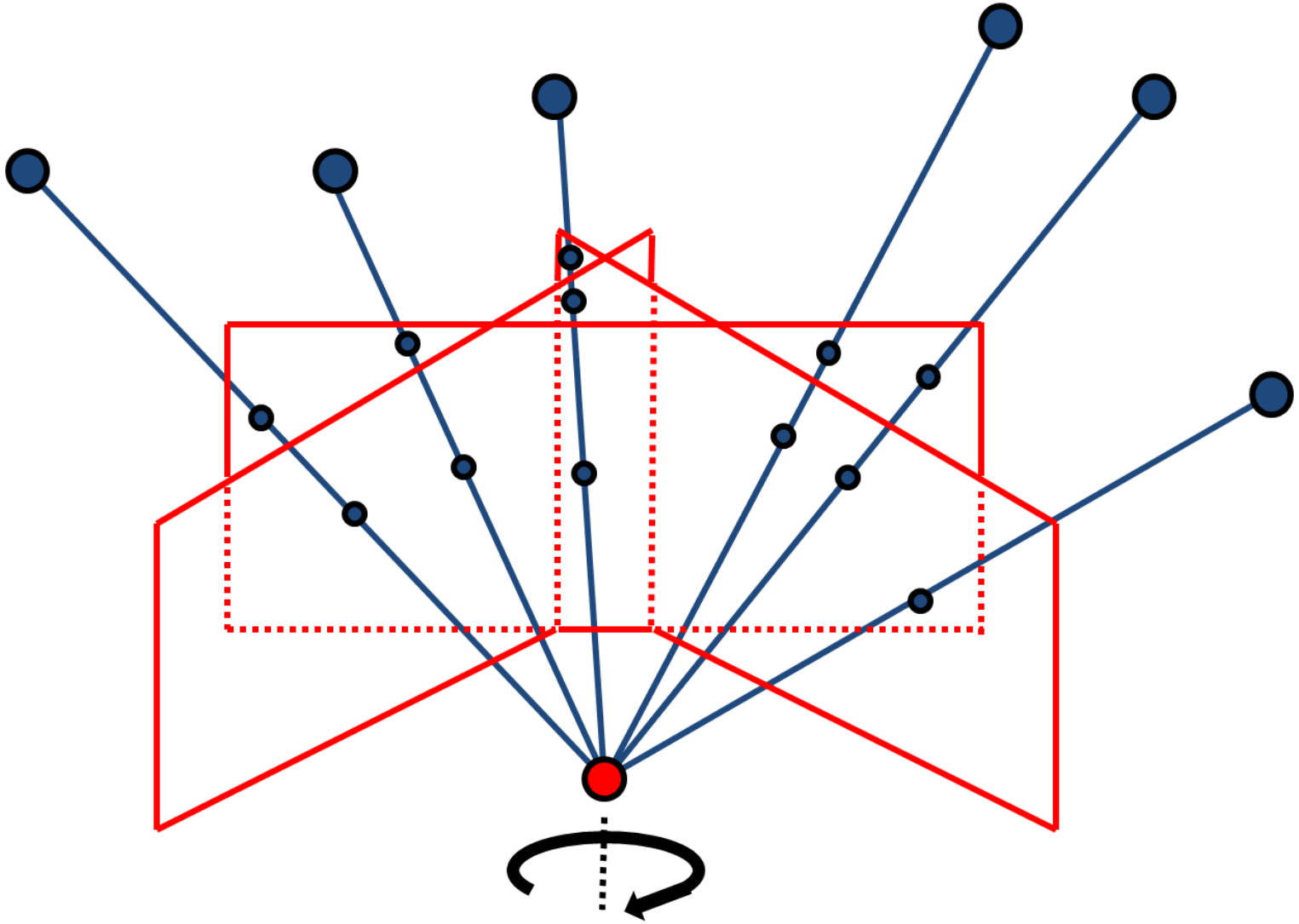
Electronics › Cameras

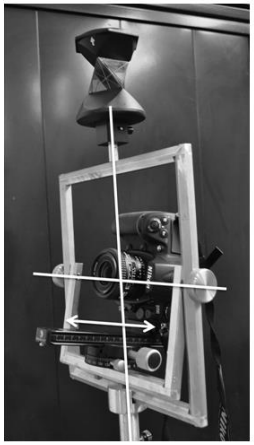
The Best 360-Degree Camera

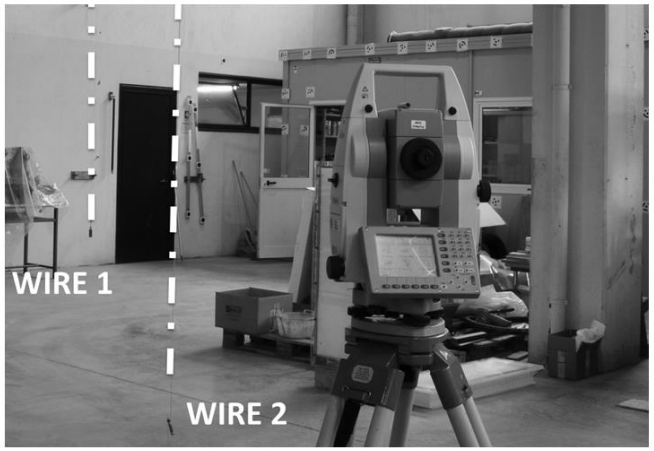
UPDATED MAY 29, 2018: We've tested the Rylo and GoPro Fusion cameras and discuss them in the Competition section.

- Photogrammetric surveys → pinhole images (normally)
  - complex scenes → several tens of images
  - no commercial solution for AAT without targets

- Main idea → few (spherical) panoramas instead of tens of images
  - large field of view (360°)
  - high resolution images (>100 megapixels)
  - automatic creation with stitching software





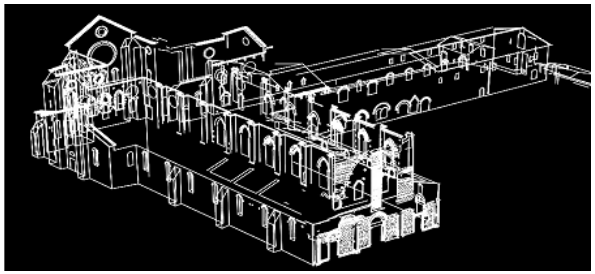


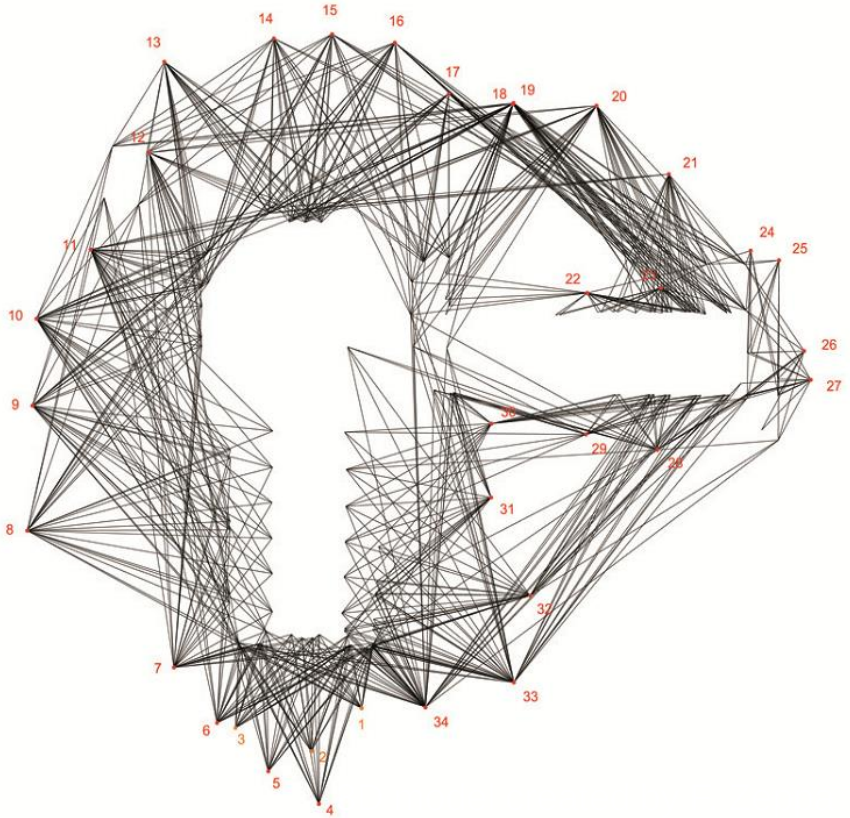
camera is centered: correct

too far back: misalignment

too far forward: misalignment

- Abbey of San Galgano

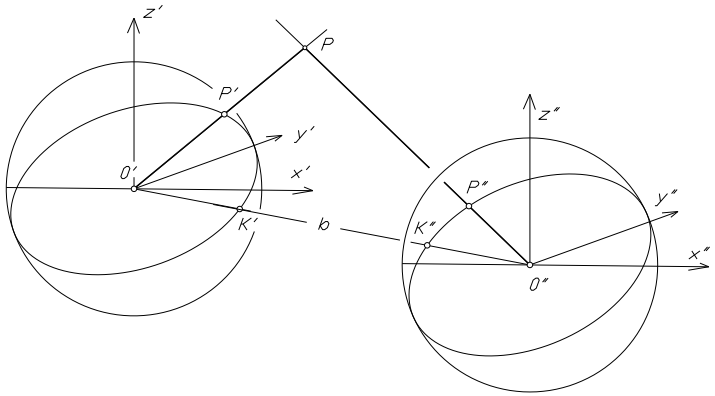




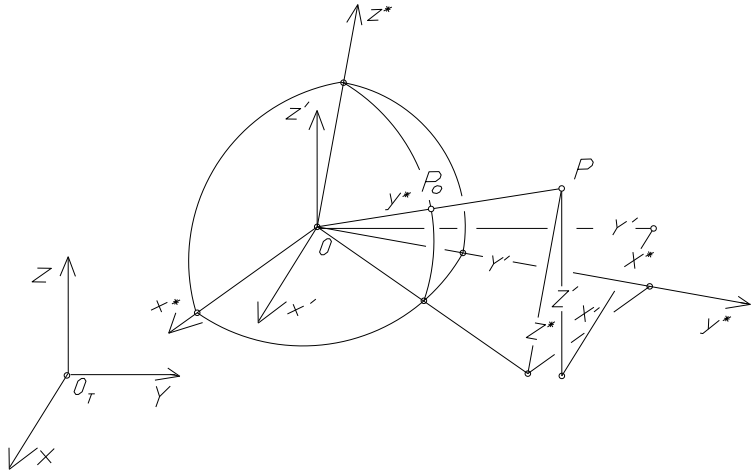
Bundle block adjustment in spherical coordinates

$$x = R \cdot \left(-\theta_0 + atg \frac{(X - X_0) - \alpha_y (Y - Y_0)}{(Y - Y_0) + \alpha_x \cdot (Z - Z_0)} \right)$$

$$y = R \cdot a\cos \frac{\alpha_y (X - X_0) - \alpha_x (Y - Y_0) + (Z - Z_0)}{\sqrt{(X - X_0)^2 + (Y - Y_0)^2 + (Z - Z_0)^2}}$$



$$\begin{bmatrix} X' & Y' & Z' \end{bmatrix} M'^{T} \begin{bmatrix} 0 & -bz & by \\ bz & 0 & -bx \\ -by & bx & 0 \end{bmatrix} M'' \begin{bmatrix} X'' \\ Y'' \\ Z'' \end{bmatrix} = 0$$



- *x*, *y* … image coordinates
- *X*, *Y*, *Z* … object 3D coordinates
- *R* … radius
- α_x, α_y … correction angles (roll and pitch)
- q_0 … heading
- X_0, Y_0, Z_0 ... centre of the sphere

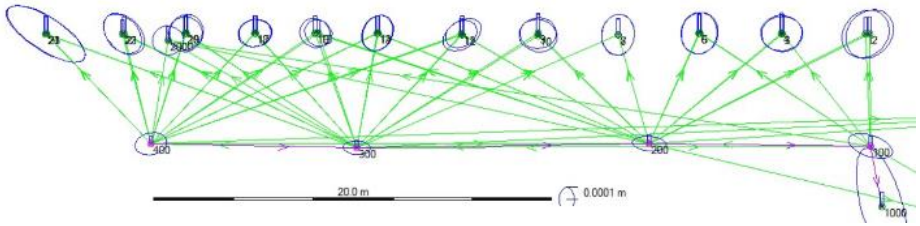
3D Arch 2017, Barazzetti et al., 3D modeling with the Samsung Gear 360

The aim of this work was to test the metric accuracy and the level of detail achievable with the Samsung Gear 360 **(350 $)**

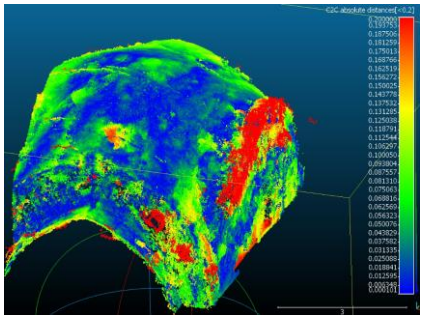
Integrated f/2.0 fisheye lenses

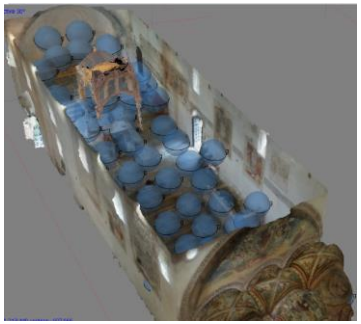
Dual 15MP CMOS sensor

Equirectangular image: 7776×3888 pix



Control points (4)		Check points (4)	
RMS XY (m)	RMS Z (m)	RMS XY (m)	RMS Z (m)
(a) projections from the mobile phone			
0.061	0.011	0.088	0.009
(b) projections from Action Direction			
0.053	0.017	0.092	0.009
(c) projections from PTGui			
0.019	0.002	0.029	0.008
(d) projections from Autopano Giga			
0.011	0.001	0.037	0.009





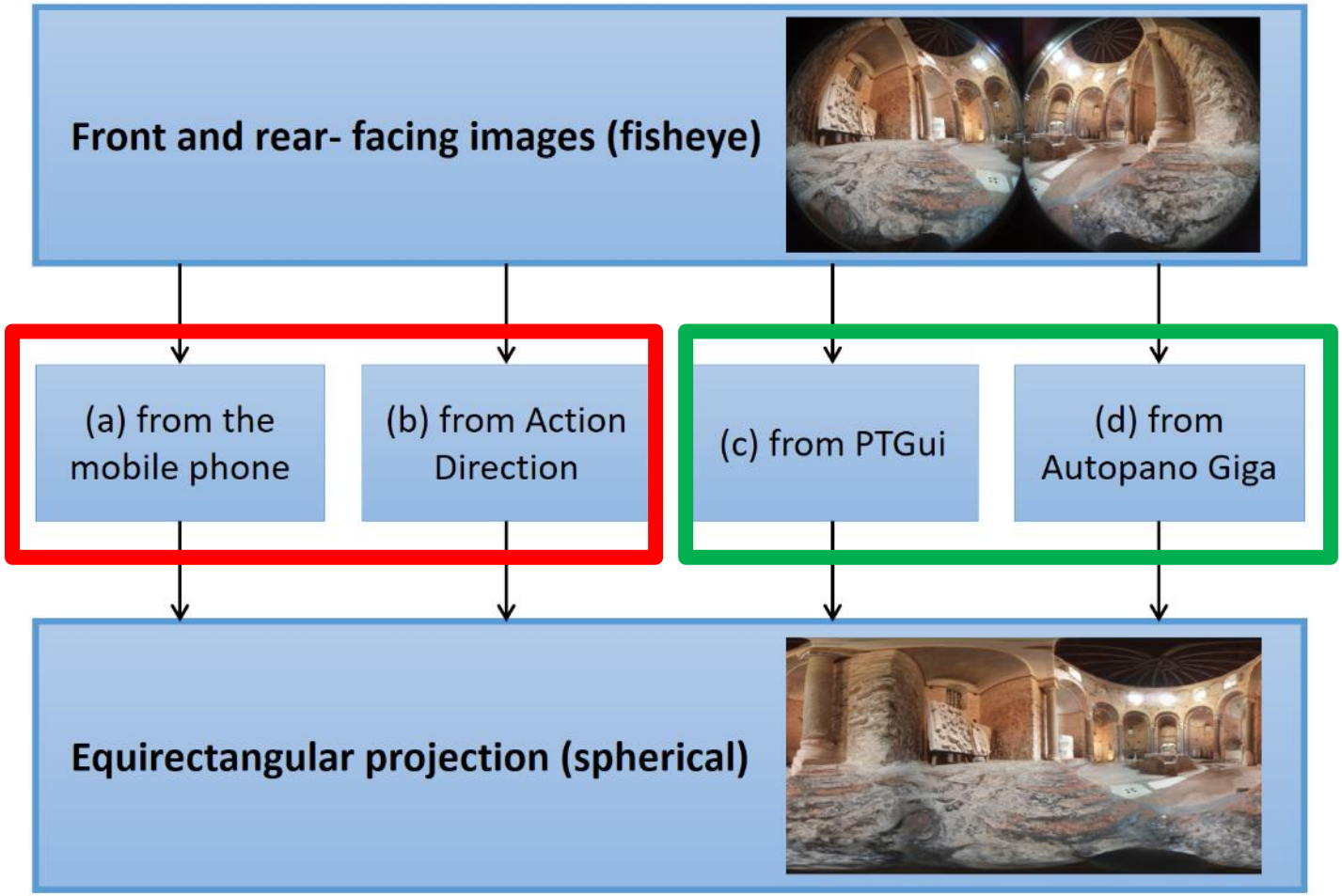
Calibration and correction before stitching

Relative metric accuracy was about 1:300

3D Arch 2017, Barazzetti et al., 3D modeling with the Samsung Gear 360

2 fisheye images

Equirectangular projection


Front and rear- facing images (fisheye)
(a) from the mobile phone
(b) from Action Direction
(c) from PTGui
(d) from Autopano Giga
Equirectangular projection (spherical)

Xiaomi Mijia Mi Sphere 360 **(300$)**

2 Integrated fisheye lenses

2 x 1/2.3 inch sensors

Equirectangular image: 6912 x 3456 pix

Direct use of the equirectangular

Projections stitched with Madventure 360

Relative metric accuracy is about 1:2000

Amazon.com: Xiaomi Mij ×

Secure | https://www.amazon.com/s/ref=nb_sb_noss?url=search-alias%3Daps&field-keywords=Xiaomi+Mijia+Mi+Sphere+360+++

Showing most relevant results. See all results for Xiaomi Mijia Mi Sphere 360.

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Mi Sphere Camera Kit 360 Degree Panoramic Camera 23.88MP 3.5K Video Recording（US Version with Warranty）

by Xiaomi

$299.99 prime

FREE Shipping on eligible orders

15

Product Features

... *360°* field of view for an unlimited experience, up to 75 minutes of ...

Xiaomi Mijia 360 Panoramic Sphere Camera Kit 23.88MP Sensor 3.5K Recording Video 6-Axis Anti-shake Waterproof with Warranty

by Xiaomi

$297.69 + $0.74 shipping

Product Features

... Modes: Flat, *Sphere*, Planet;6-axis ... carry; The APP "*Mi* Home" support ...

SONY

RESOLUTION. SPEED. POWER. α7R III.

SHOP NOW

"Xiaomi Mi Sphere" See all 11 results...

Madventure 360 Camera, 4K Video, 24MP Photo, Waterproof, Selfie-Stick and Tripod Included

by MADV

$309.99 prime

Samsung Gear 360 Real 360° High Resolution VR Camera (US Version with Warranty)

by Samsung

$65.78 ~~$349.99~~ prime

YI 360 VR Camera Dual-Lens 5.7K HI Resolution Panoramic Camera with Electronic Image Stabilization, 4K in-Camera...

by YI

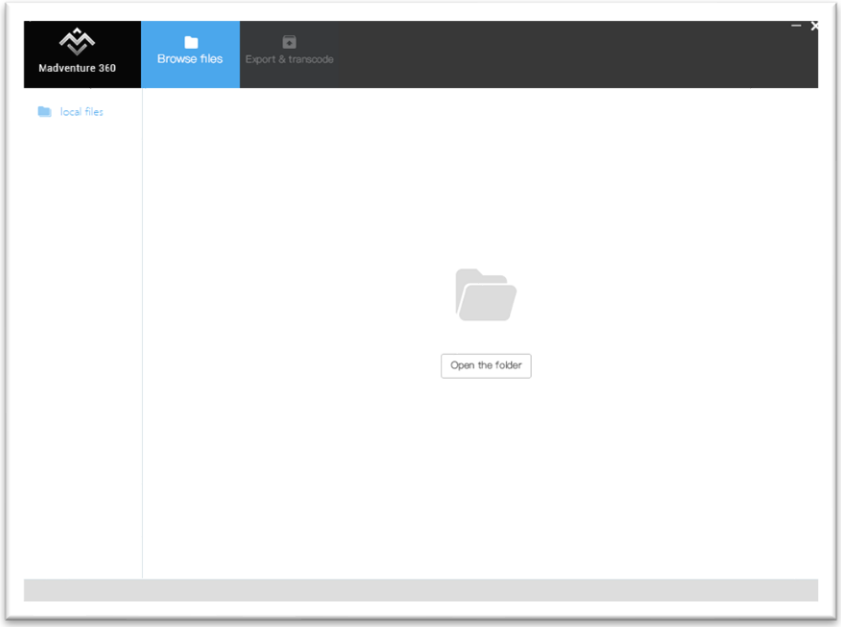
Insta360 ONE 360 Camera, Sports and Action Video Camera, VR Camera, 24MP (7K) Photos, 4K Videos for iPhone All...

by insta360

$299.00 prime

Image acquisition

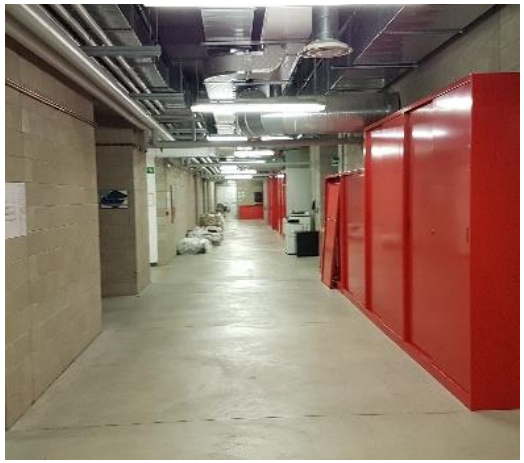
Generation of equirectangular projections with Madventure 360



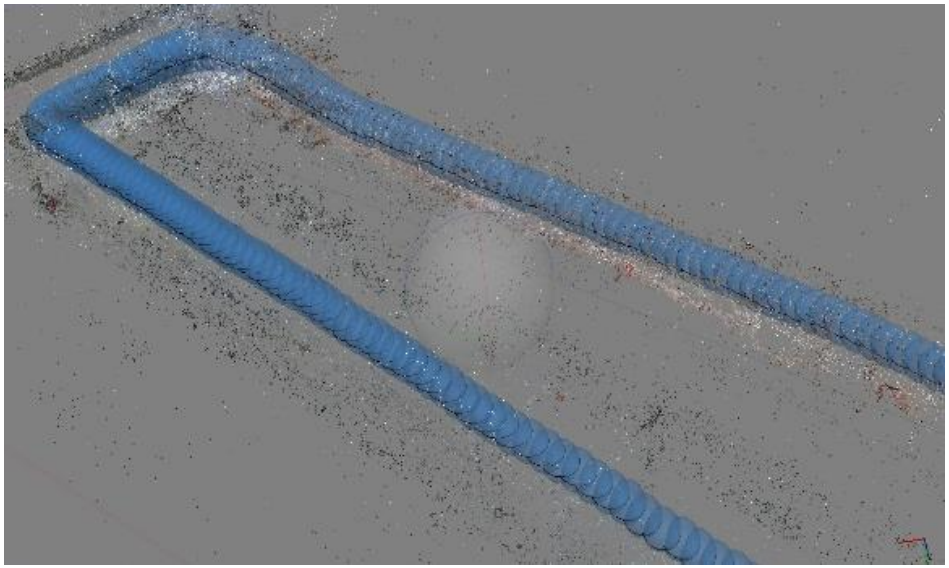
Survey of long and narrow spaces

Corridor image sequence

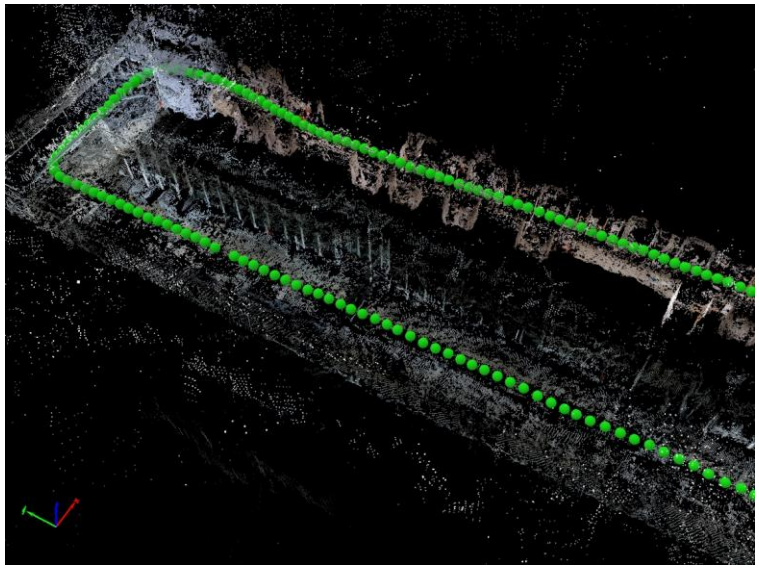
(more than 200 images)



Photoscan

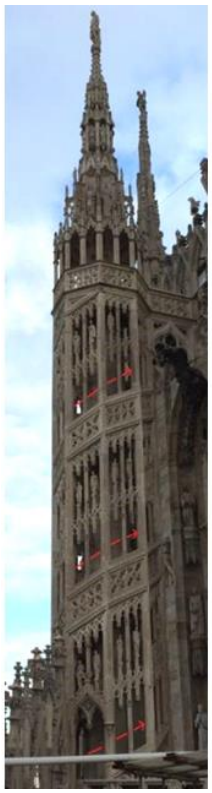


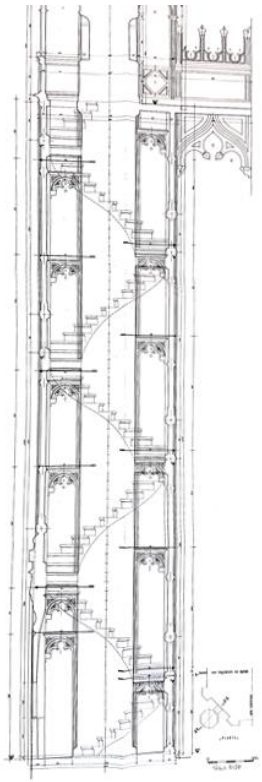
Pix4Dmapper



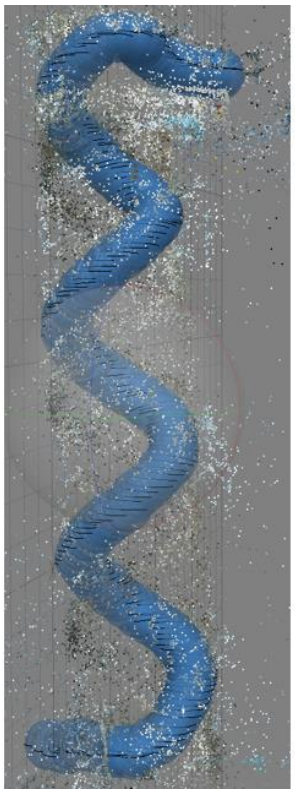
Survey of long and narrow spaces

Staircase → 222 images





Photoscan



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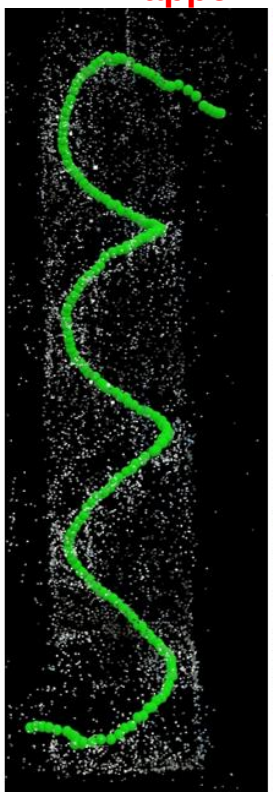
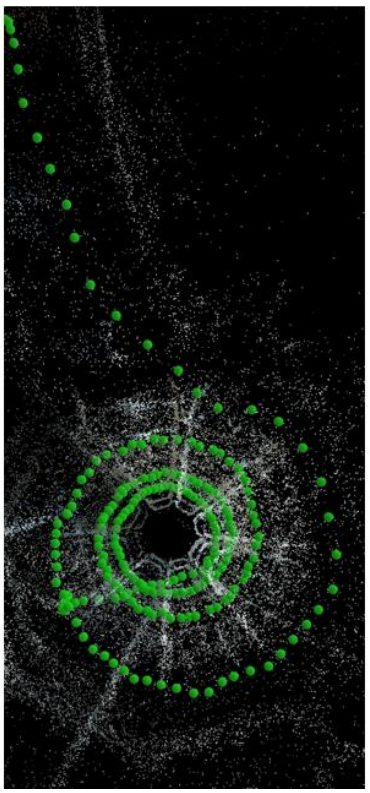
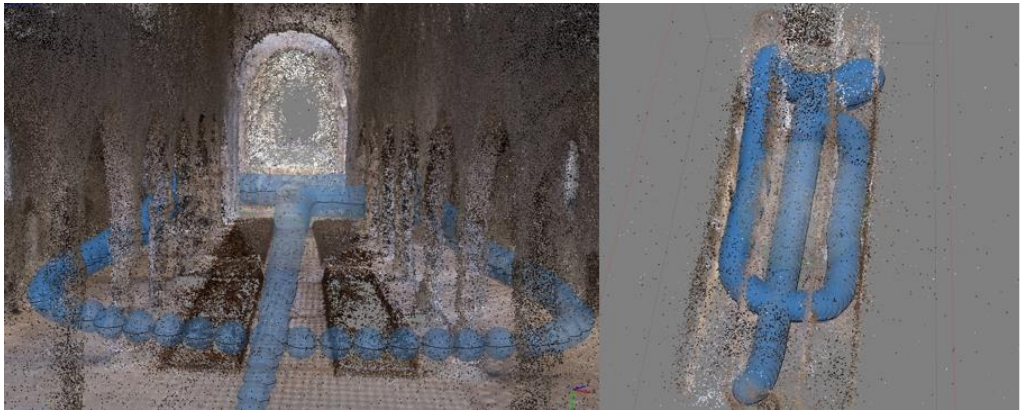


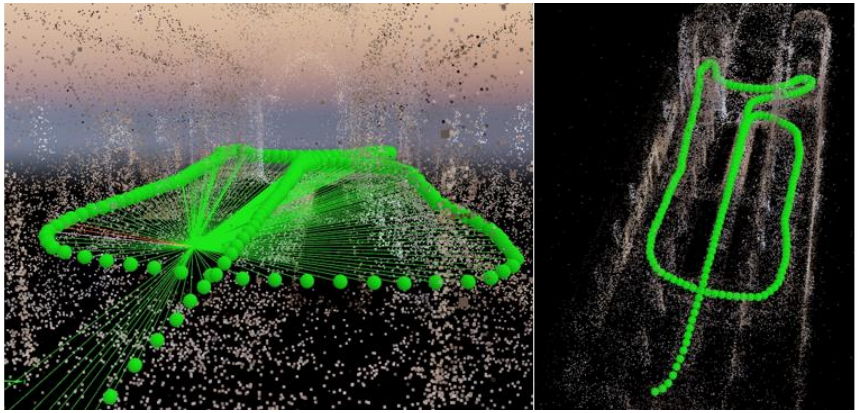


Survey of long and narrow spaces

Basilica (237 images)



Photoscan



Pix4Dmapper

Metric evaluation of the Xiaomi Mijia Mi Sphere 360

Image orientation

↓

Dense point cloud generation

↓

Mesh production

↓

Orthophoto production

Test with GCPs and TS

↓

Test with laser scanner

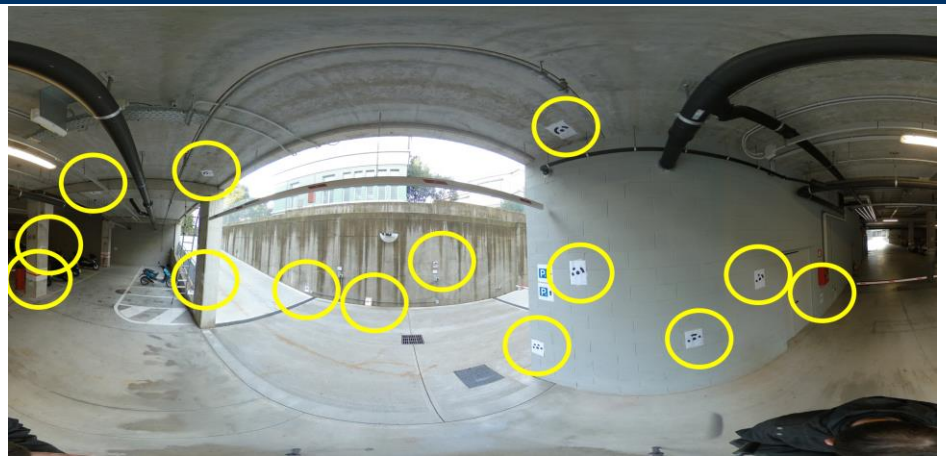
↓

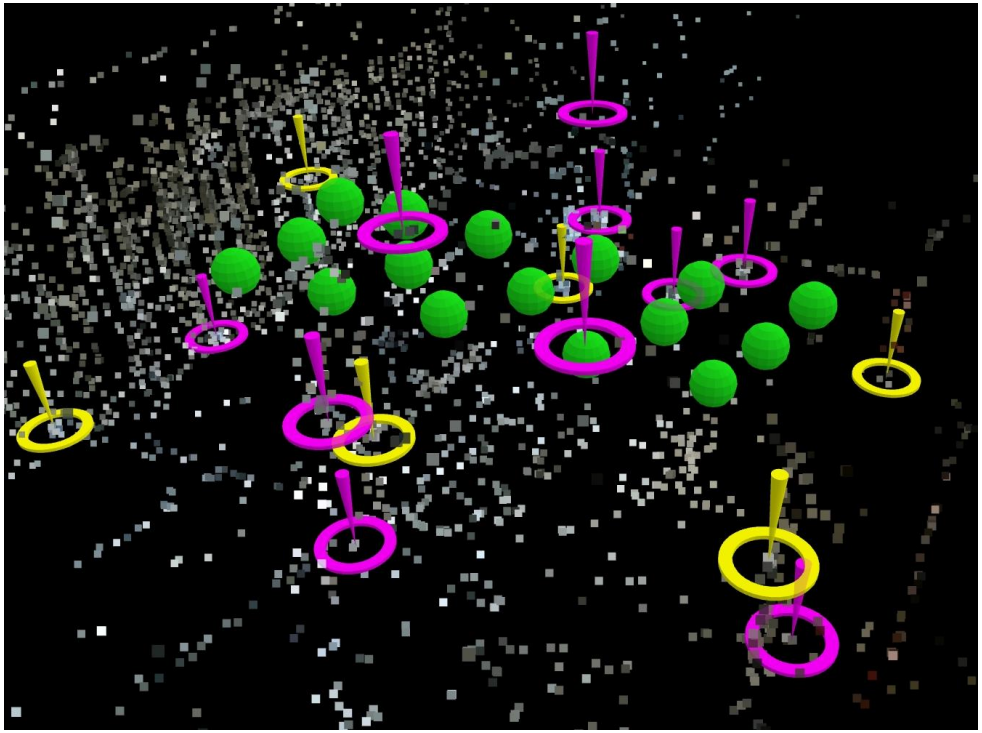
Test with central perspective images

Image orientation accuracy

15 spherical images

Targets measured with a total station





Image

Control point

Check point

Pix4Dmapper

Metric accuracy evaluation

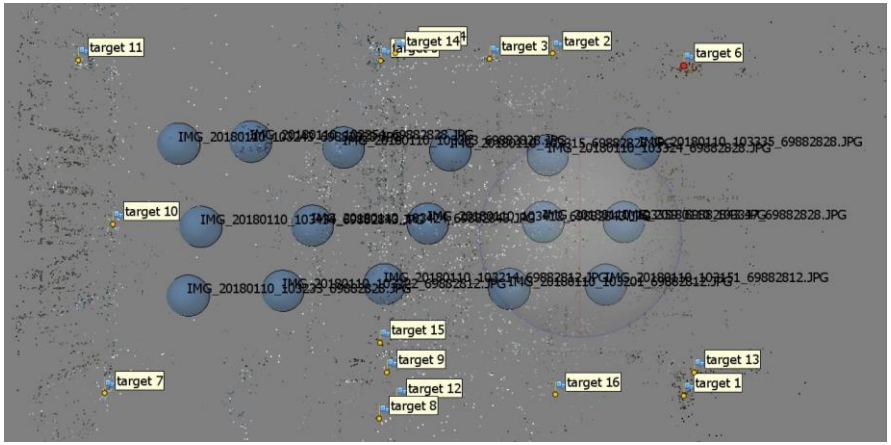
Size of the area: 10.9 m x 6 m x 3.7 m

- 6 control points
- 11 check points

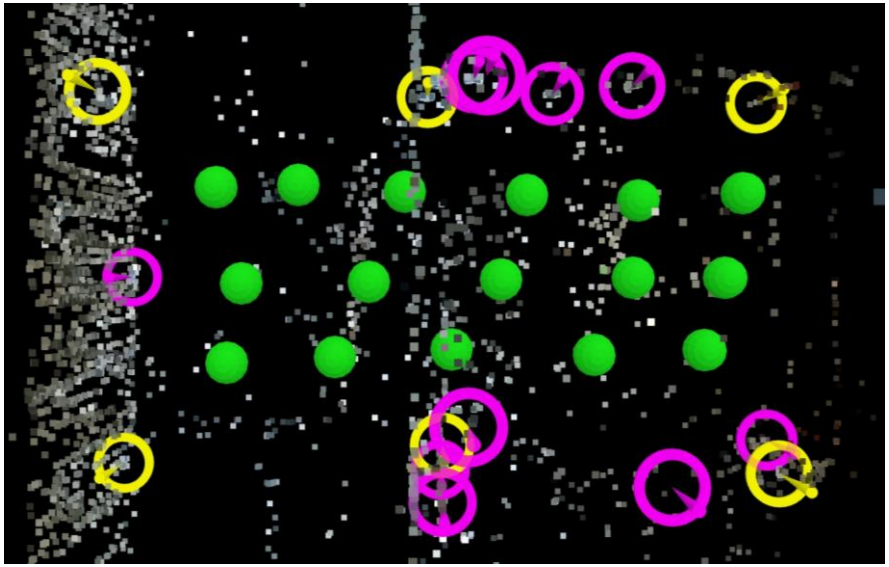
11 Check points	*RMSE X (mm)*	*RMSE Y (mm)*	*RMSE Z (mm)*
PhotoScan	6.8	7.2	6.7
Pix4Dmapper	5.2	4.6	5.9

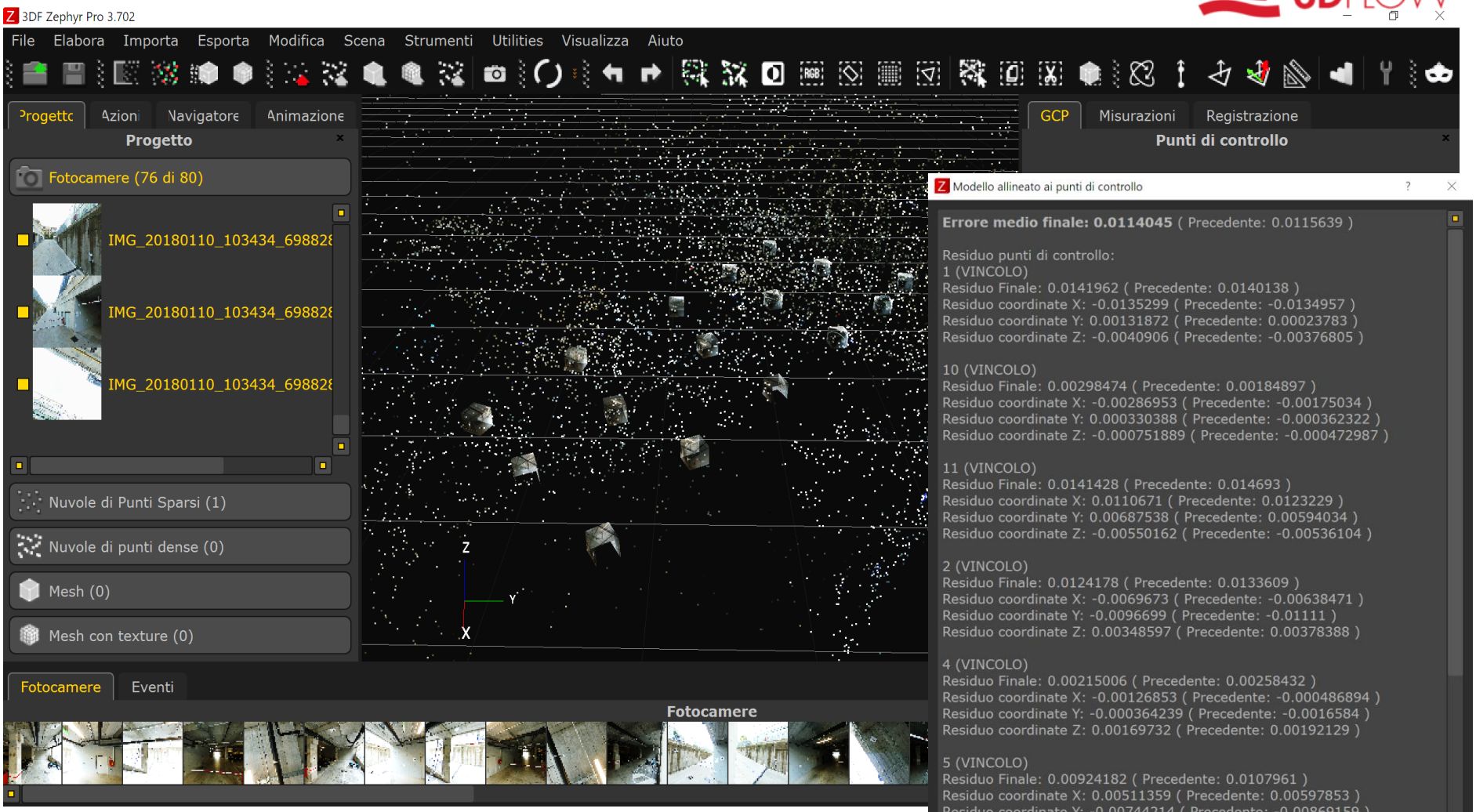
Relative accuracy about 1:2000

Photoscan



Pix4Dmapper



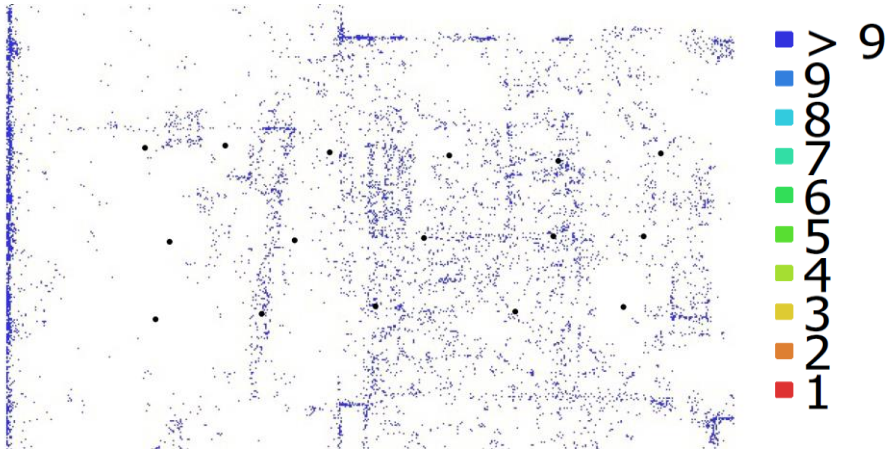

3DF Zephyr Pro 3.702
File Elabora Importa Esporta Modifica Scena Strumenti Utilities Visualizza Aiuto
Progetto Azioni Navigatore Animazione
Progetto
Fotocamere (76 di 80)
IMG_20180110_103434_698828
IMG_20180110_103434_698828
IMG_20180110_103434_698828
Nuvole di Punti Sparsi (1)
Nuvole di punti dense (0)
Mesh (0)
Mesh con texture (0)
GCP Misurazioni Registrazione
Punti di controllo
Fotocamere Eventi
Fotocamere
Modello allineato ai punti di controllo
Errore medio finale: 0.0114045 (Precedente: 0.0115639)
Residuo punti di controllo:
1 (VINCOLO)
Residuo Finale: 0.0141962 (Precedente: 0.0140138)
Residuo coordinate X: -0.0135299 (Precedente: -0.0134957)
Residuo coordinate Y: 0.00131872 (Precedente: 0.00023783)
Residuo coordinate Z: -0.0040906 (Precedente: -0.00376805)
10 (VINCOLO)
Residuo Finale: 0.00298474 (Precedente: 0.00184897)
Residuo coordinate X: -0.00286953 (Precedente: -0.00175034)
Residuo coordinate Y: 0.000330388 (Precedente: -0.000362322)
Residuo coordinate Z: -0.000751889 (Precedente: -0.000472987)
11 (VINCOLO)
Residuo Finale: 0.0141428 (Precedente: 0.014693)
Residuo coordinate X: 0.0110671 (Precedente: 0.0123229)
Residuo coordinate Y: 0.00687538 (Precedente: 0.00594034)
Residuo coordinate Z: -0.00550162 (Precedente: -0.00536104)
2 (VINCOLO)
Residuo Finale: 0.0124178 (Precedente: 0.0133609)
Residuo coordinate X: -0.0069673 (Precedente: -0.00638471)
Residuo coordinate Y: -0.0096699 (Precedente: -0.01111)
Residuo coordinate Z: 0.00348597 (Precedente: 0.00378388)
4 (VINCOLO)
Residuo Finale: 0.00215006 (Precedente: 0.00258432)
Residuo coordinate X: -0.00126853 (Precedente: -0.000486894)
Residuo coordinate Y: -0.000364239 (Precedente: -0.0016584)
Residuo coordinate Z: 0.00169732 (Precedente: 0.00192129)
5 (VINCOLO)
Residuo Finale: 0.00924182 (Precedente: 0.0107961)
Residuo coordinate X: 0.00511359 (Precedente: 0.00597853)
Residuo coordinate Y: -0.00744214 (Precedente: -0.00869159)
Residuo coordinate Z: 0.001969 (Precedente: 0.00229534)
Ok

Additional consideration n. 1

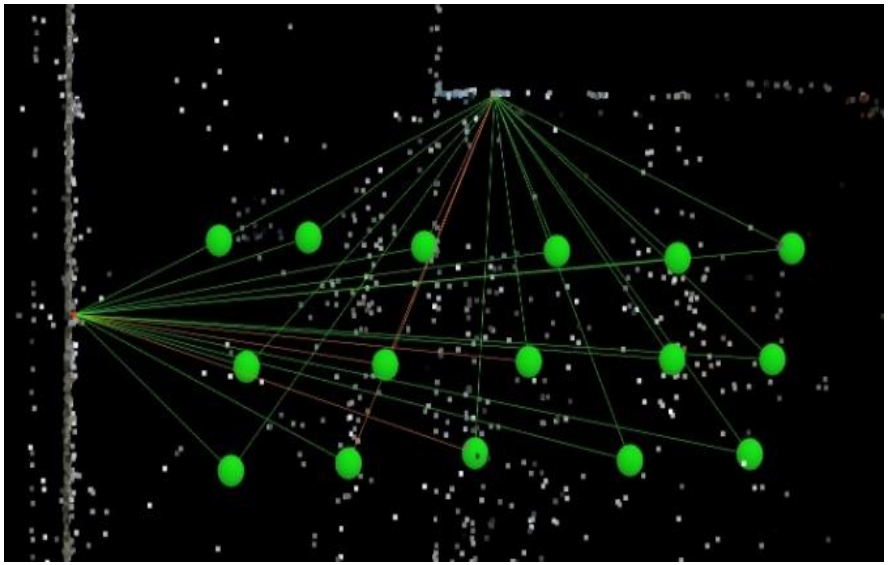
Points matched in several images

100% overlap!

Photoscan



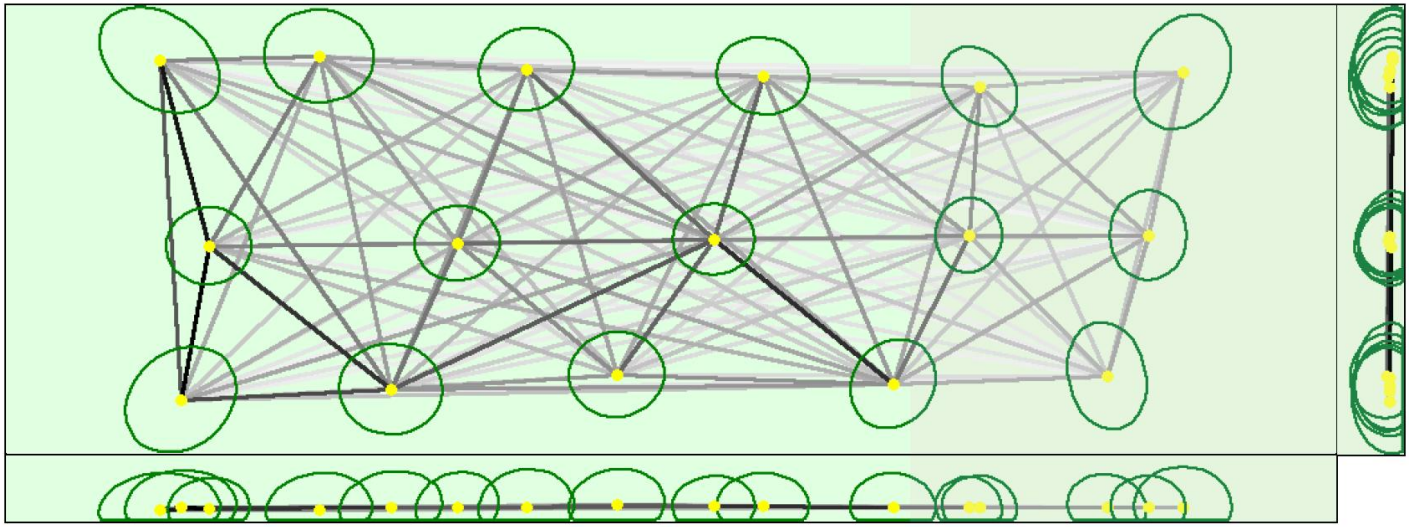
Pix4Dmapper



Additional consideration n. 2

Graphic visualization of error ellipses for camera locations

Similar to geodetic networks



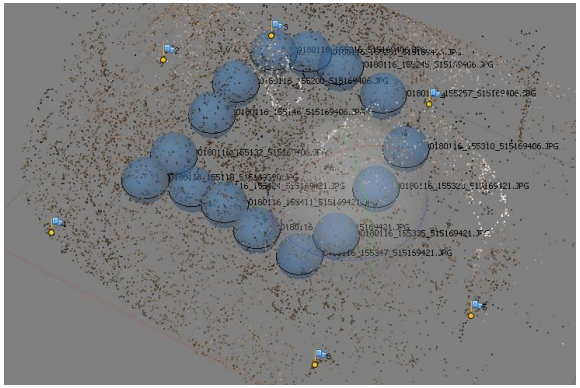
Pix4Dmapper

Problems in experiments with rolled images

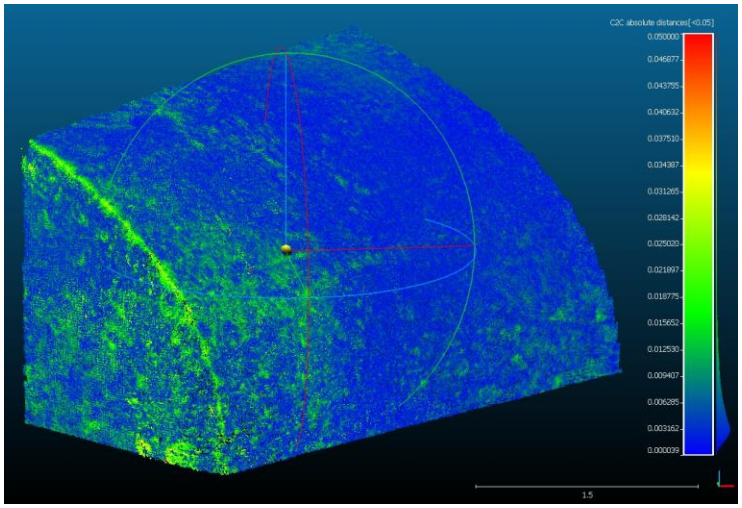
Rotation of 90° (roll) → failure of bundle adjustment

Dense point cloud generation

15 spherical images acquired inside a historic cellar



PhotoScan

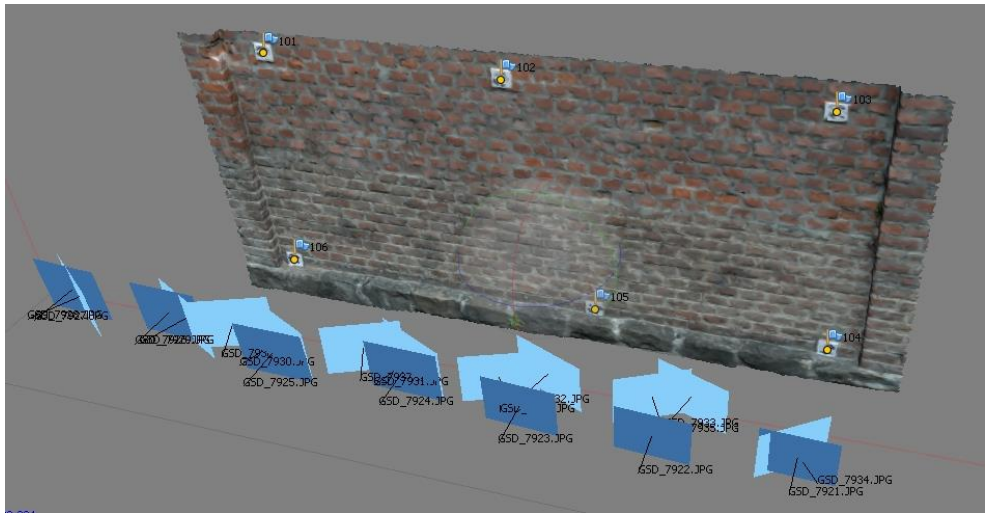


Comparison with laser scans (Faro Focus 3D)

± 5 mm discrepancy

Orthophoto production

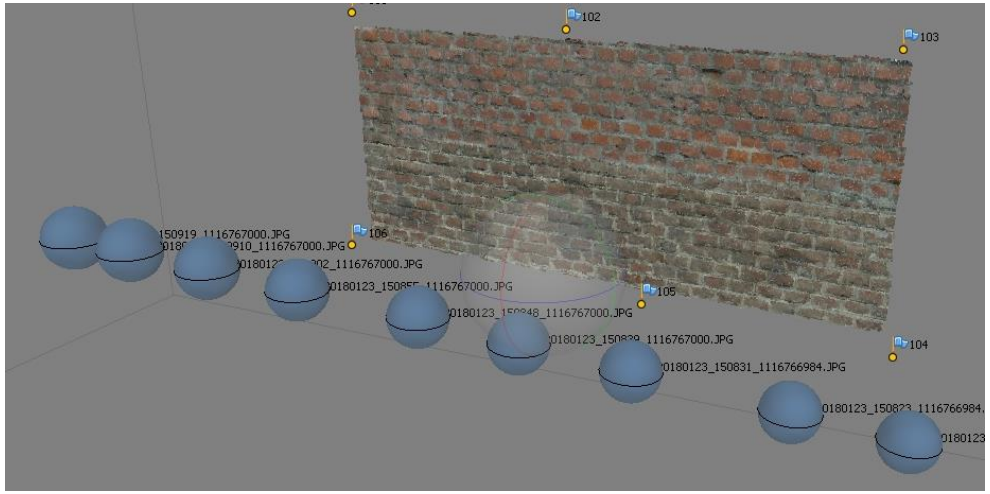
Wall with good texture (bricks)



Nikon D610 + 20 mm

Average camera object - distance 1.7 m
GSD: 0.5 mm

(Normal + Convergent images)



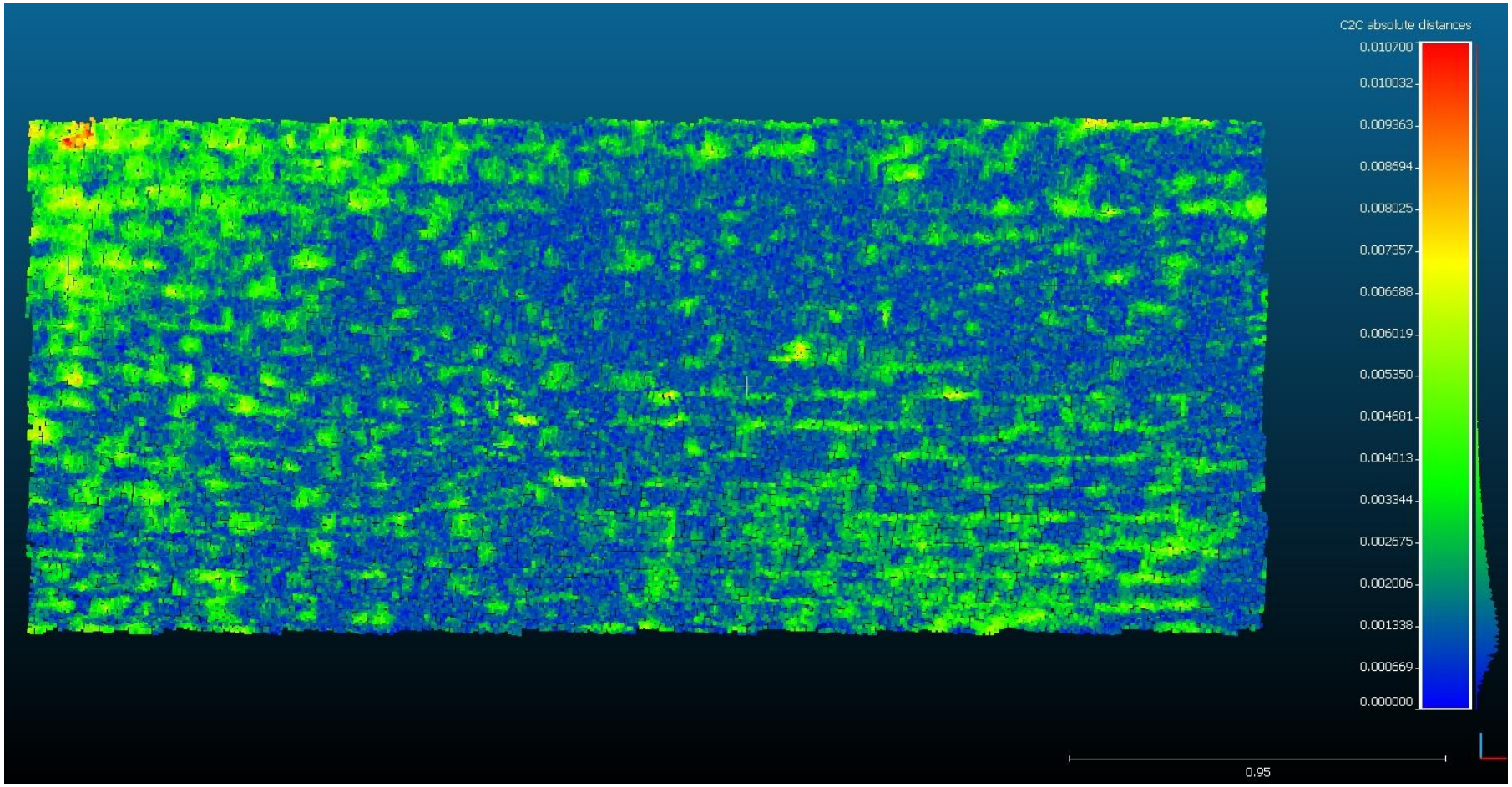
Xiaomi Mijia Mi Sphere 360

Average camera object - distance 1.5 m
GSD: 1.3 mm

(Convergent images??)

Overall, 3 time worse

Comparison of point clouds generated in the two projects



Overall discrepancy: ±2.5 mm

Orthophoto production

Nikon D610

Pixel size: 0.5 mm

Xiaomi Mijia
Mi Sphere 360

Pixel size: 2 mm

Linking in/out: illumination conditions!

Illumination conditions!

Valid solution for the survey of long and narrow spaces

Metric accuracy with the Xiaomi Mijia Mi Sphere 360: 0.5 – 1.5 pixels

24 megapixels on a 360 field of view is not a very high resolution

GSD of a spherical project is 3-6 times worse than the same project with central perspective lenses

Image acquisition very simple: camera pointed at any direction

Illumination conditions: big problem for 360 images