A Shape-Adjusted Tridimensional Reconstruction of Cultural Heritage Artifacts Using a Miniature Quadrotor

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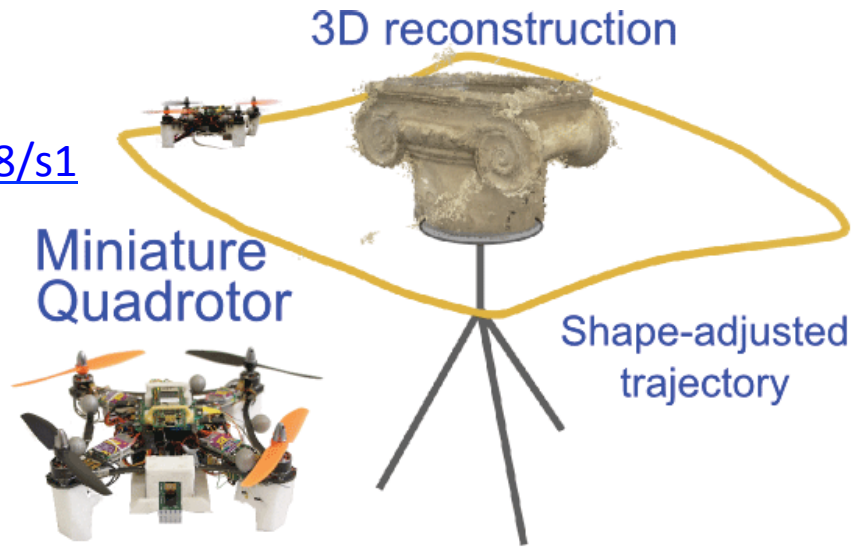
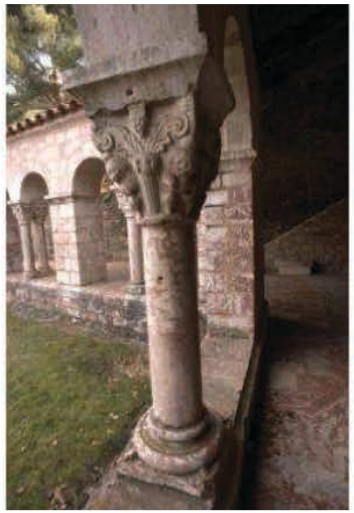


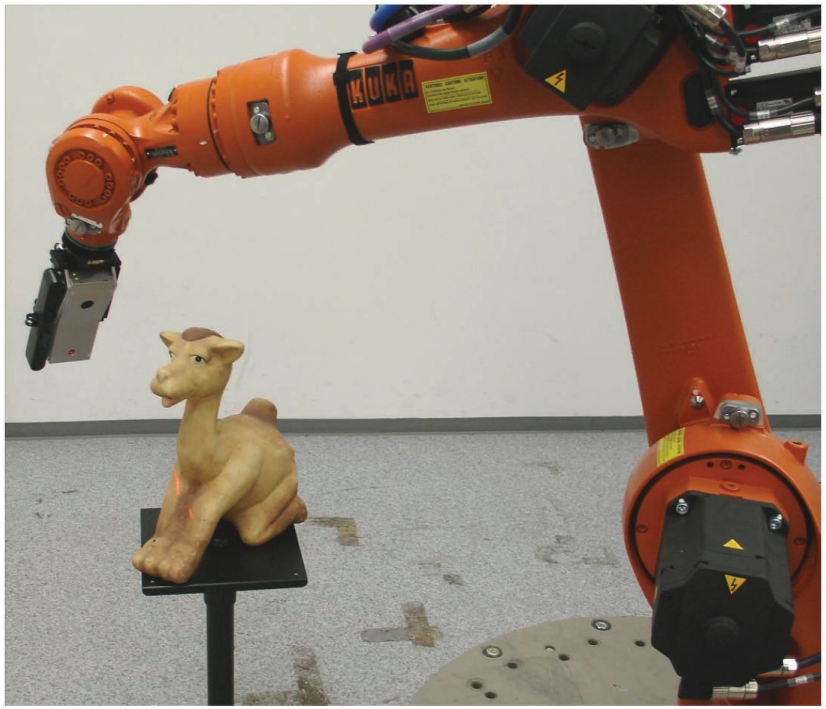
Remote Sens. 2016, 8(10), 858; doi:10.3390/rs8100858

Architectural elements

- Dimensions: ca 30x150 cm
- Number of images: ca 150
- Processing time: ca 3 hours
- Representation: 3D model



Pierrot-Deseilligny, M.; De Luca, L.; Remondino, F. (2011)



Kriegel, S. et al. IROS 2012

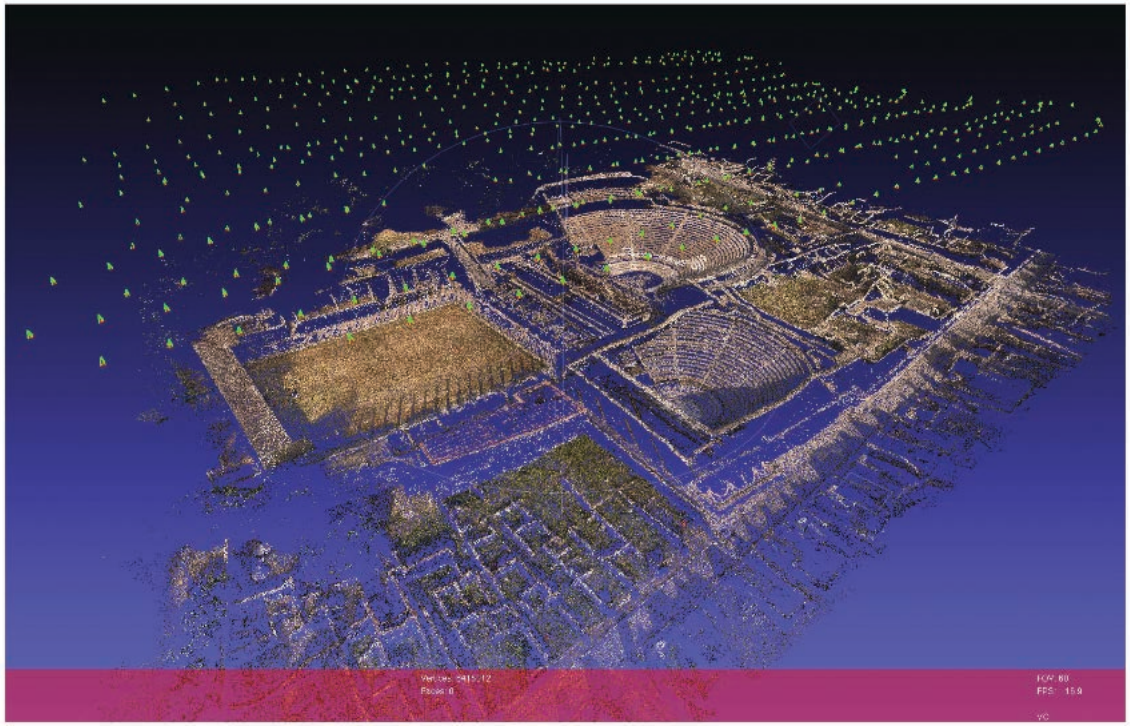


Fig. 2. Tie points extraction and the flight path.

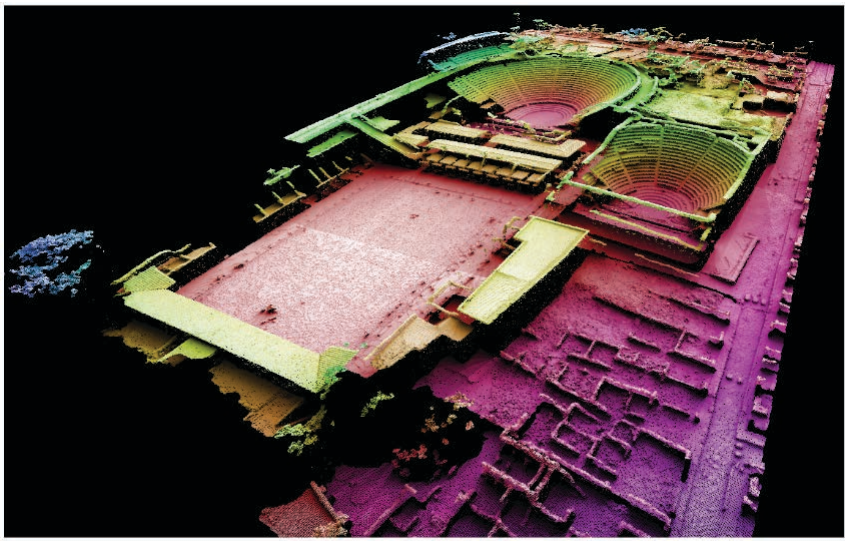


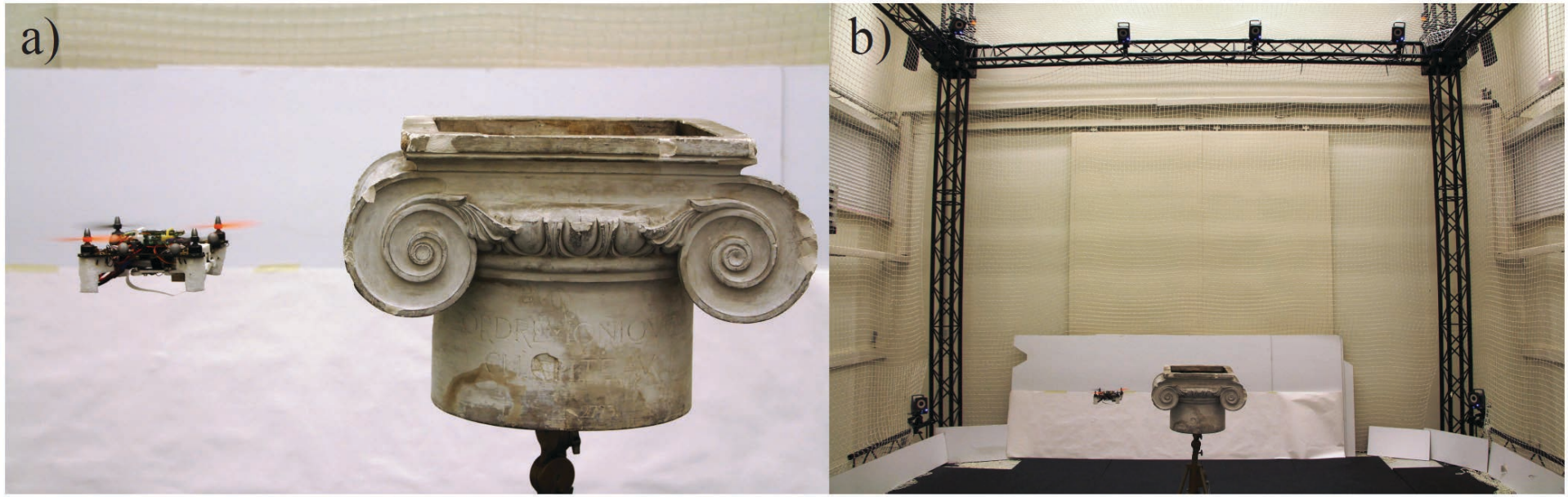
Fig. 6. The dense point cloud of the area.

Salari R. et al. (2013)

Fig. 7. The Odeon dense point cloud.

X4-MaG quadrotor

(weight: 367 grams; endurance: 10 min)



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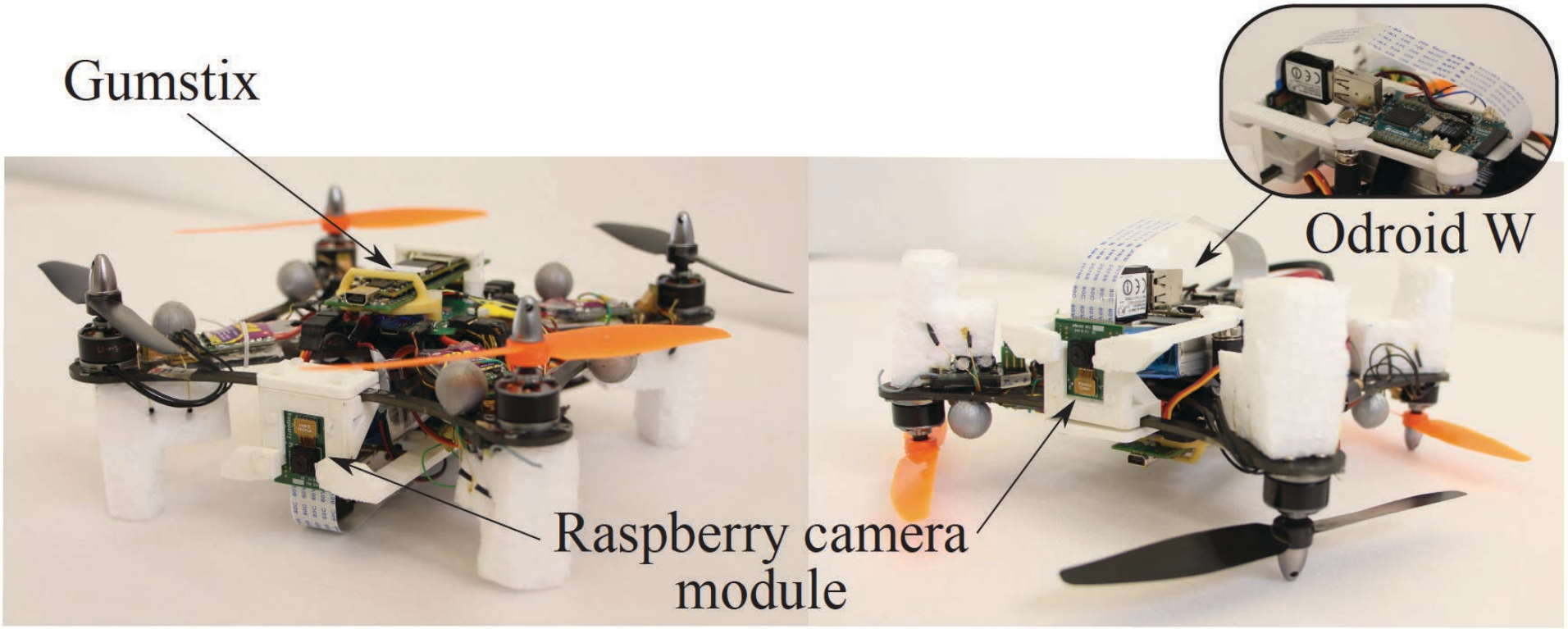
X4-MaG robot

with an Odroid W board and its small 5-Mpx Raspberry Camera Module



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Raspberry PI Camera module

	Specifications
Mass (g)	3
Resolution (Mpx)	5
Field of view (°)	$53.50 \pm 0.13 \times 41.41 \pm 0.11$
Image Sensor area (mm^2)	3.76×2.74
Pixel size (μm^2)	1.74×1.74
Signal to Noise Ratio (SNR) (dB)	36

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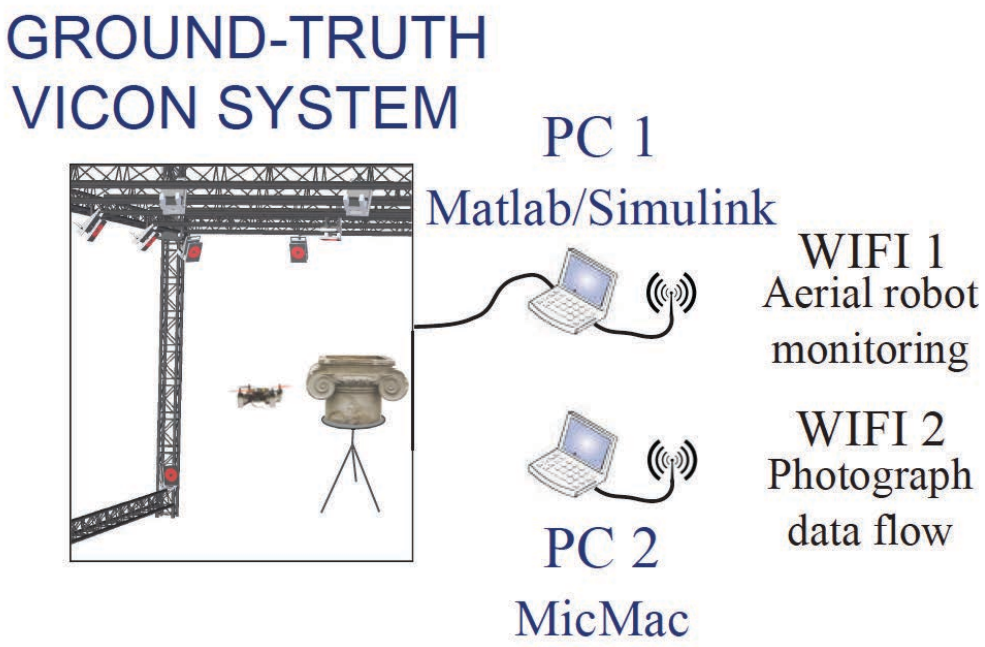
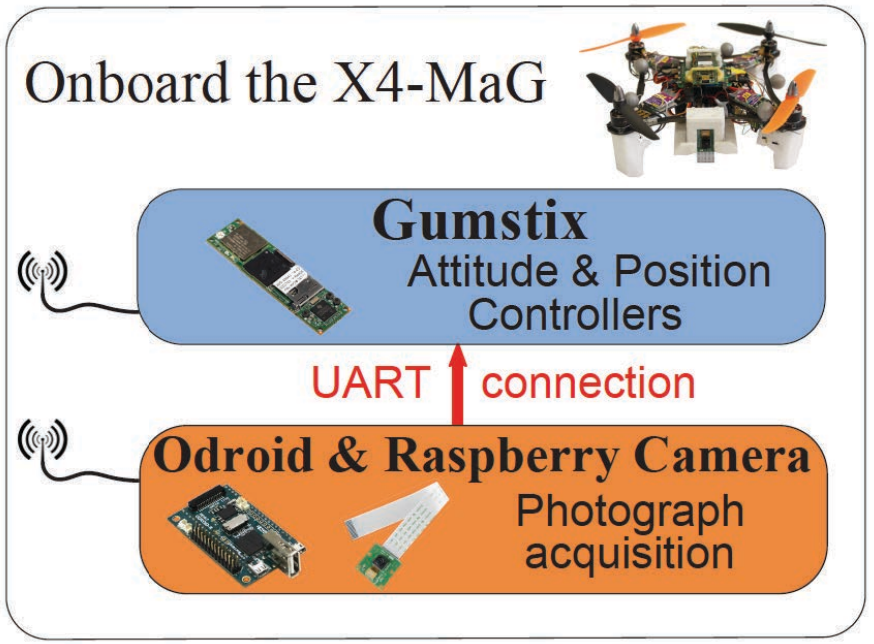
Interconnection between the various systems





The Odroid board also communicates with the Gumstix thanks to a UART serial connection and enables us to record the camera's position while the photograph acquisition is being performed.

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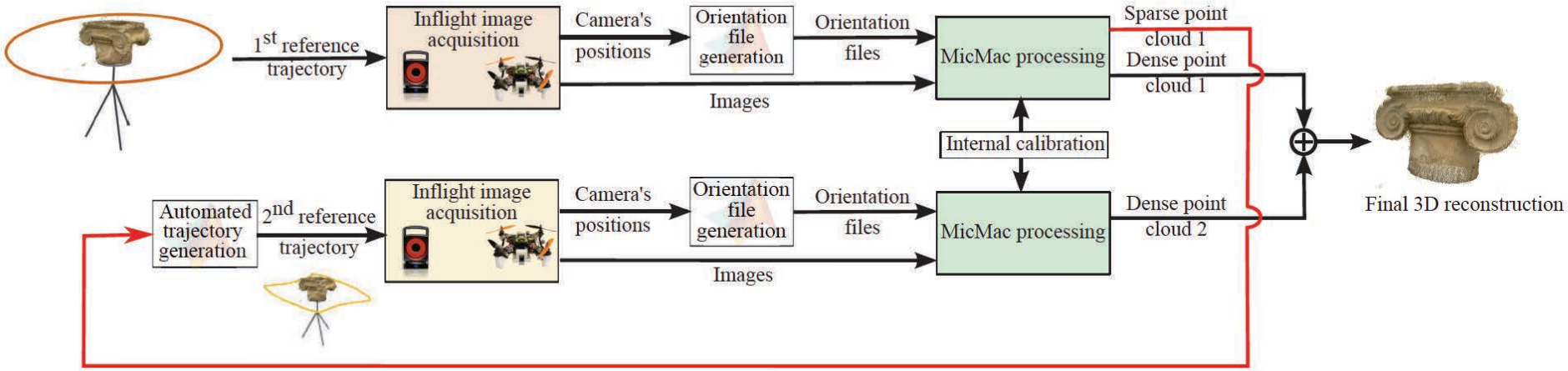
Dense matching of the APERO/MICMAC photogrammetric toolchain

The theoretical pipeline consists of:

- Tie-point extraction (using the/an SIFT algorithm) and image-pair recognition,
- Internal and external calibrations and global orientation of each image based on bundle adjustment,
- Dense image matching, resulting in the final point cloud.

Global overview of the final dense point cloud generation



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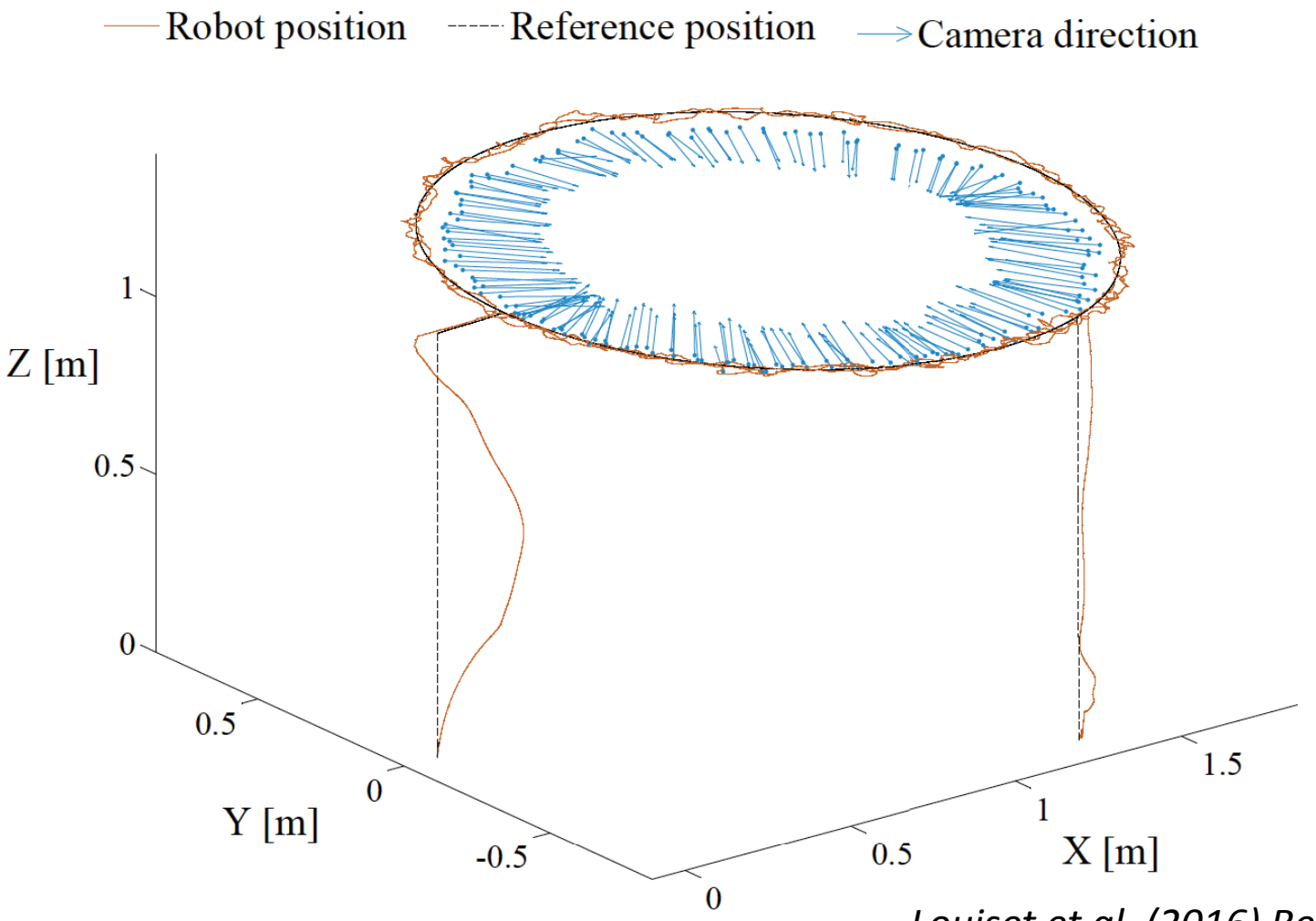
3D view of the first circular trajectory

(giving the camera's direction and the robot's position) (v=2.5 cm·s^{-1})



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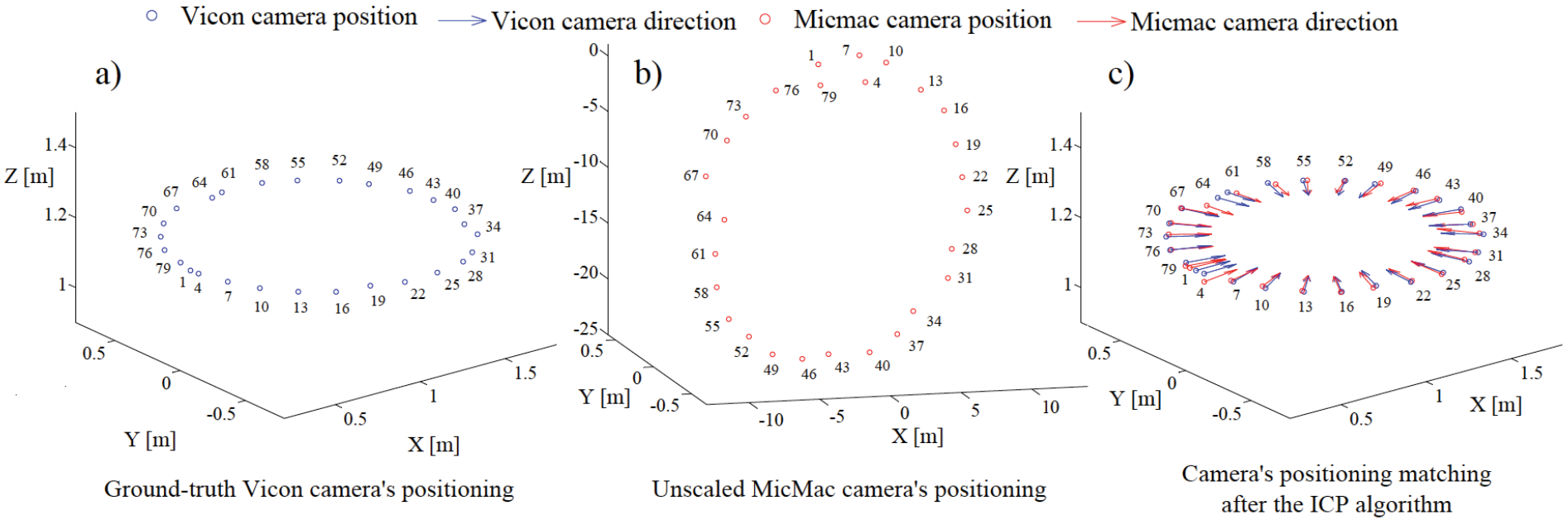
Orientation matching between the camera positions estimated by MicMac and given by the Vicon system



Ground-truth Vicon camera's positioning

Unscaled MicMac camera's positioning

Camera's positioning matching after the ICP algorithm

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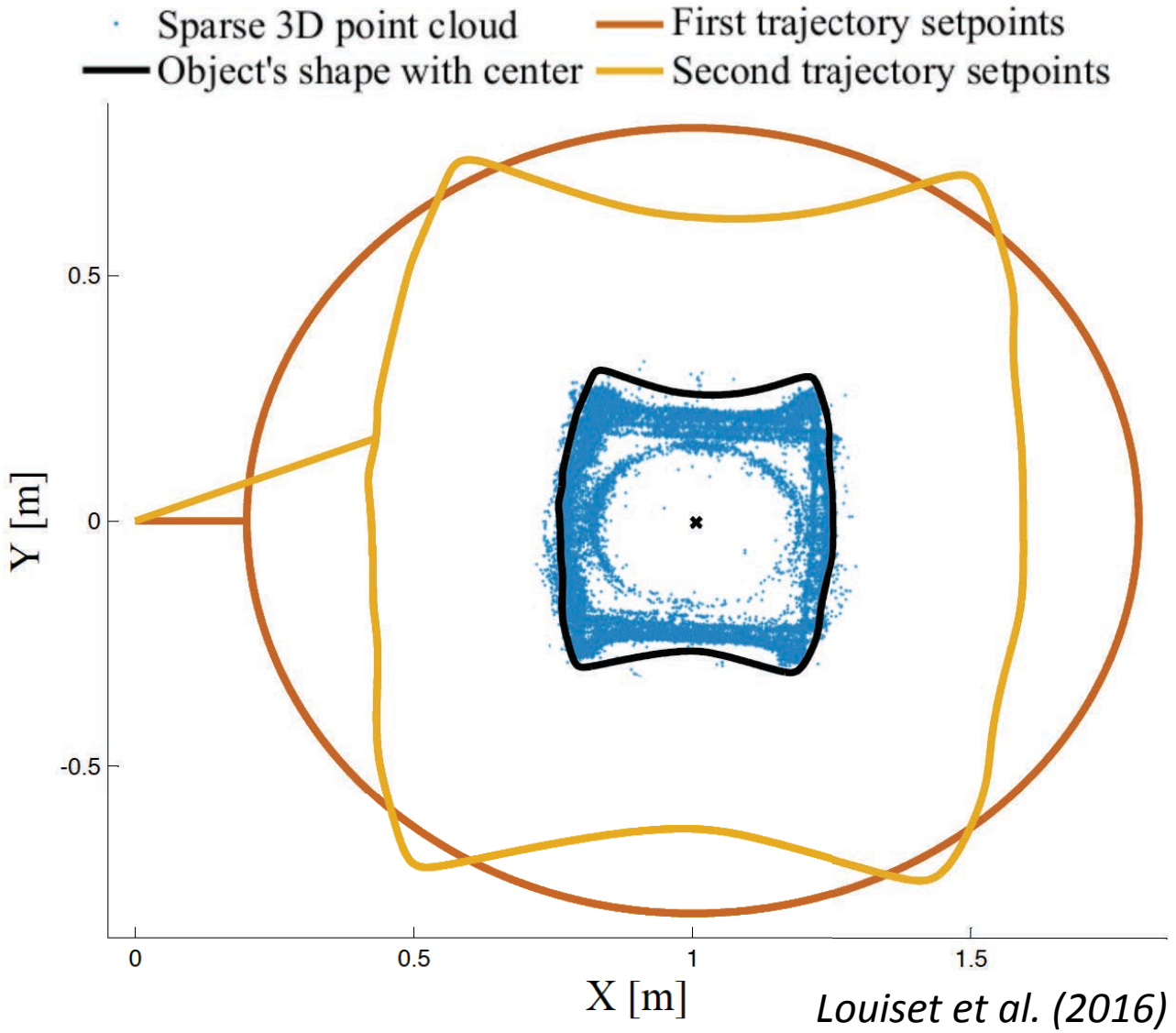
Second Trajectory: Smart Trajectory Depending on the Artifact's Shape



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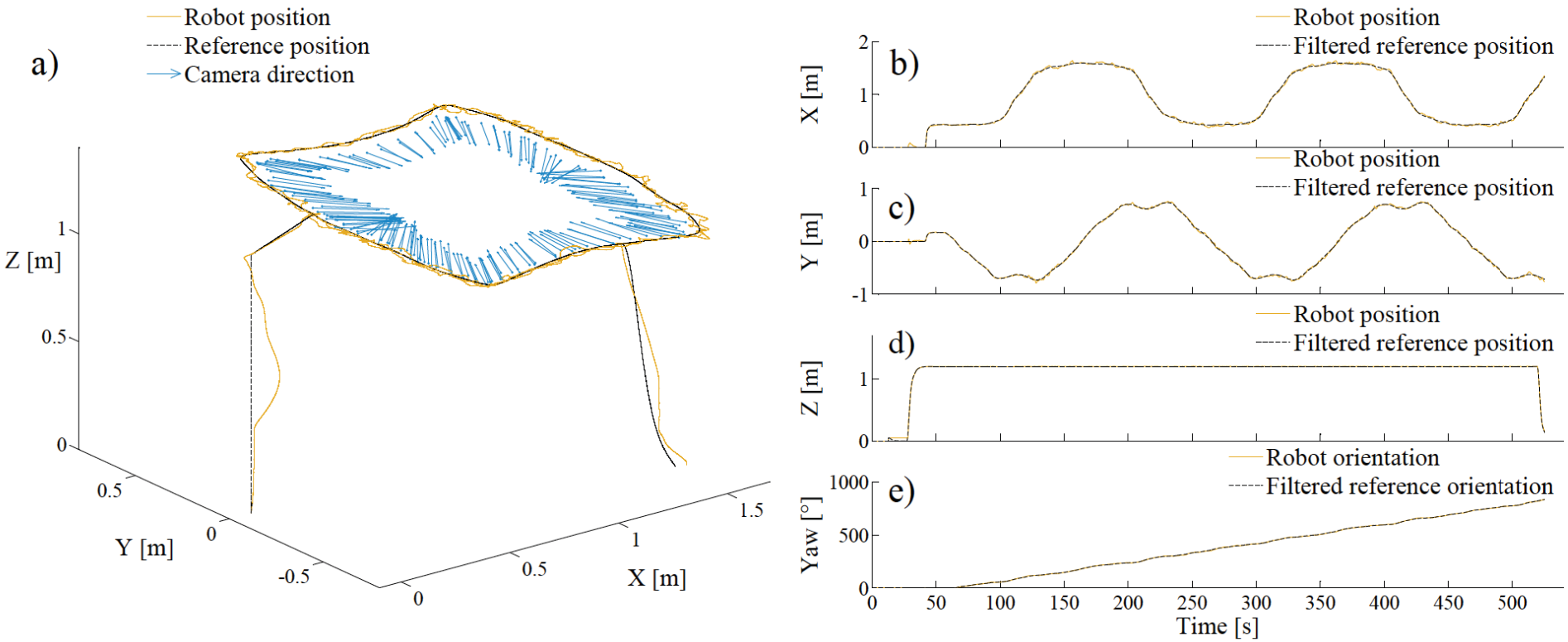
3D view of the second trajectory ($v=2.5\ cm \cdot s^{-1}$)



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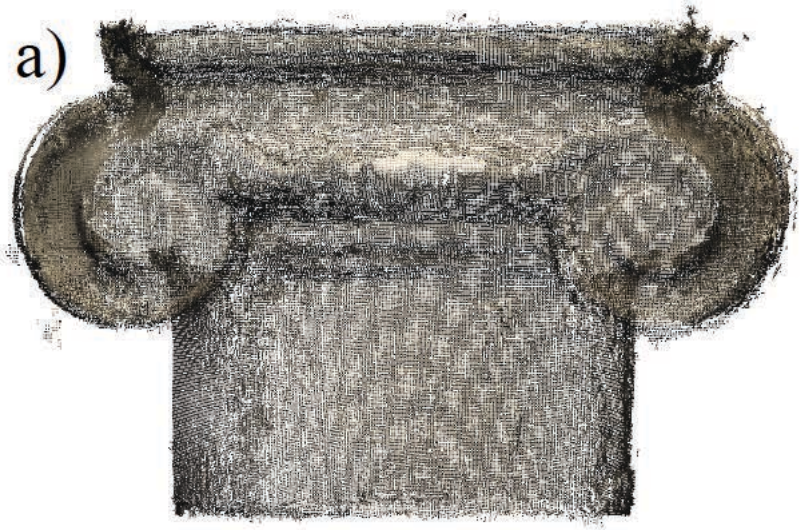
a)



3D model from
the 1st flight

b)

3D model from
the 2nd flight

c)

Final 3D model
combining both flights

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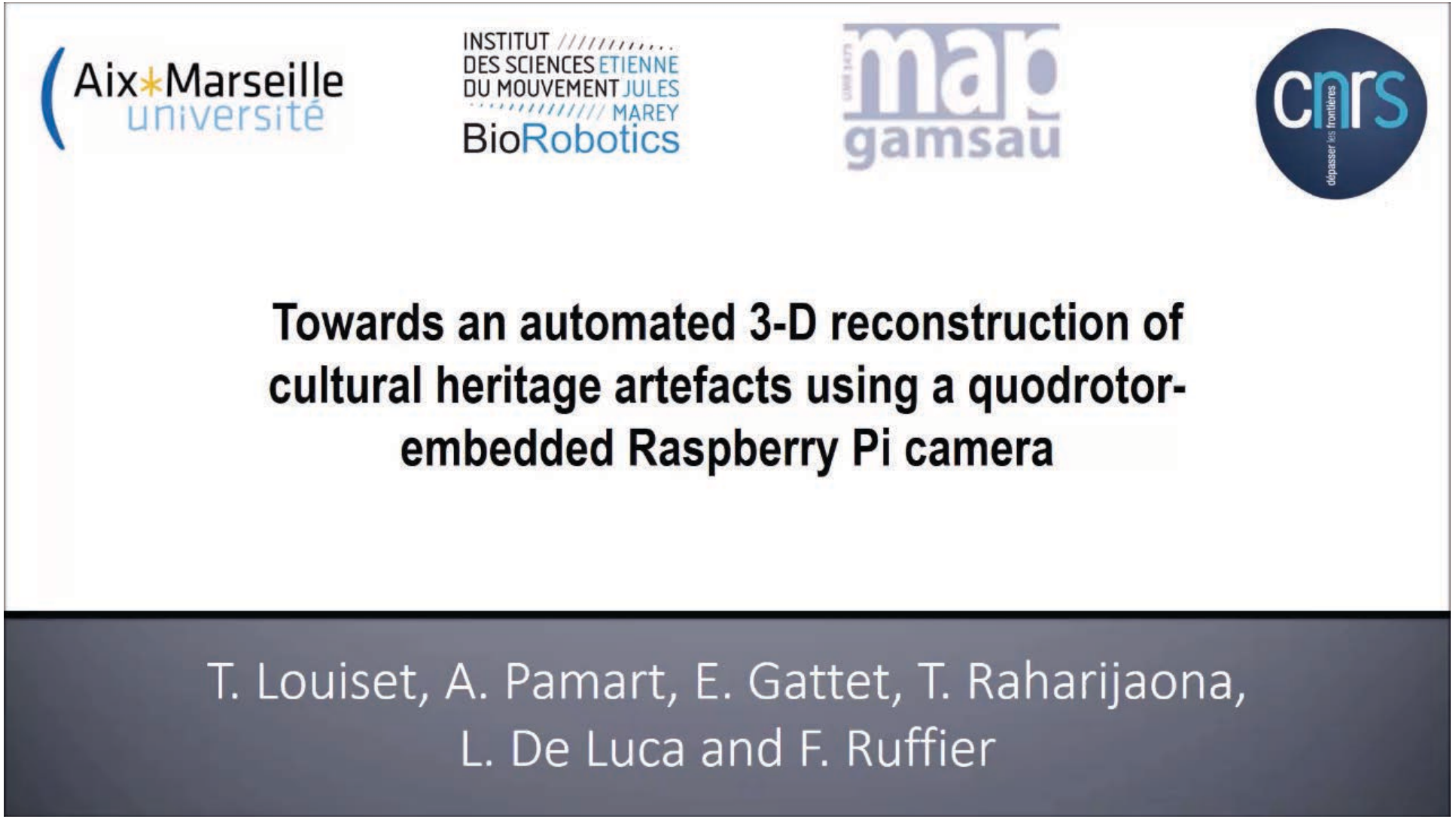

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Camera Devices

Table 5. Parameters of the camera devices.

	Automated Quadrotor Embedded Raspberry Pi Camera	**Manual Reflex Nikon D90 Operated by a Photographer**
Sensor size (mm^2)	3.76×2.74	23.6×15.8
Resolution (megapixels)	5	12.9
Image resolution (pixels)	2592×1944	4288×2848
Pixel-size (μ m)	1.4	5.5
Focal length (mm)	3.6	38
35-mm equivalent focal length	36	58

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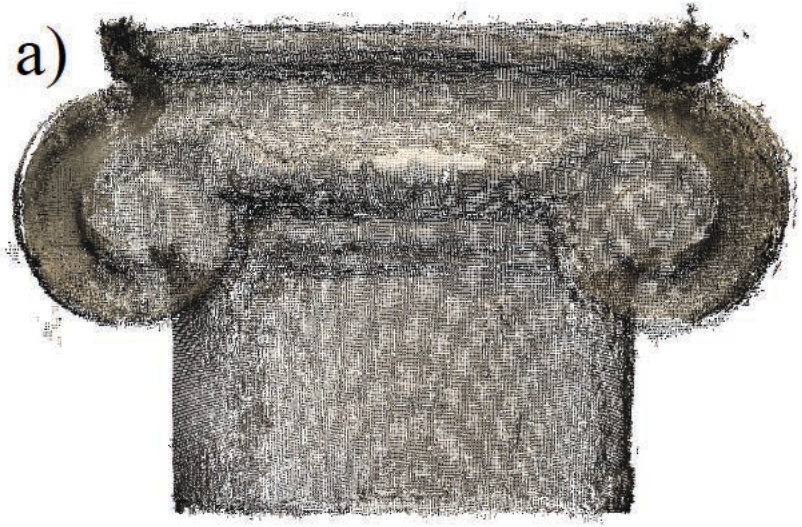

3D model from
the 1st flight

3D model from
the 2nd flight

Final 3D model
combining both flights

3D model from the Nikon D90 -
human driven acquisition

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Metric comparison

Table 6. Metric comparison between the reconstructed 3D models.

	Automated Quadrotor Embedded Raspberry Pi Camera			**Manual Reflex Nikon D90 Operated by a Photographer**
Distance (m)	0.7			1.2
GSD (mm)	0.27			0.16
Graphical Error (mm)	2.7			0.24
	Calib	Traj1	Traj1 + Traj2	
Residue (px)	0.37	2.22	2.77	1.22
Number of pictures	11	180	360	37
Metric residue ($mm \cdot px^{-1}$)	7.4			0.3
Subsampling (px/line)	8			8
Point-cloud GSD (mm)	2.16			1.28
Number of points	34,000			348,000

Three hundred sixty photographs were taken in-flight every 2 s at a linear speed of 2.5 cm·s−1

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Perspectives

- To use a miniature camera endowed with an internal stabilizer,

- To reduce the infrastructure cost

$\Rightarrow$ Need of accurate timing synchronization

$\Rightarrow$ Need to determine the camera's position and direction accurately.

Conclusion

- Production of a 3D model of a cultural heritage artifact

- Improved efficiency of close-range photogrammetric methods in terms of their completeness, accuracy and quickness

=> A third trajectory? : voxels quantification until occlusion will be totally filled

=> Rigid block stereo pair system ? to help the dense matching process