Method for spherical camera to 3D LiDAR calibration and synchronization with example on Insta360 X4 and LiVOX MID 360

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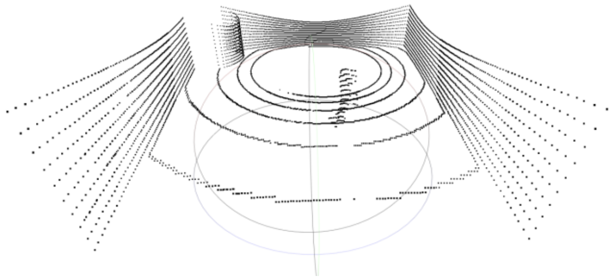
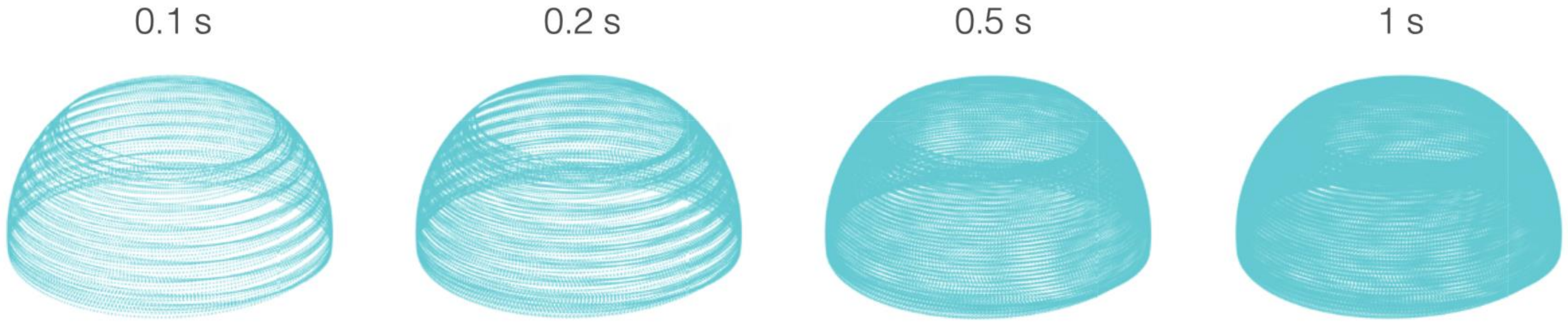
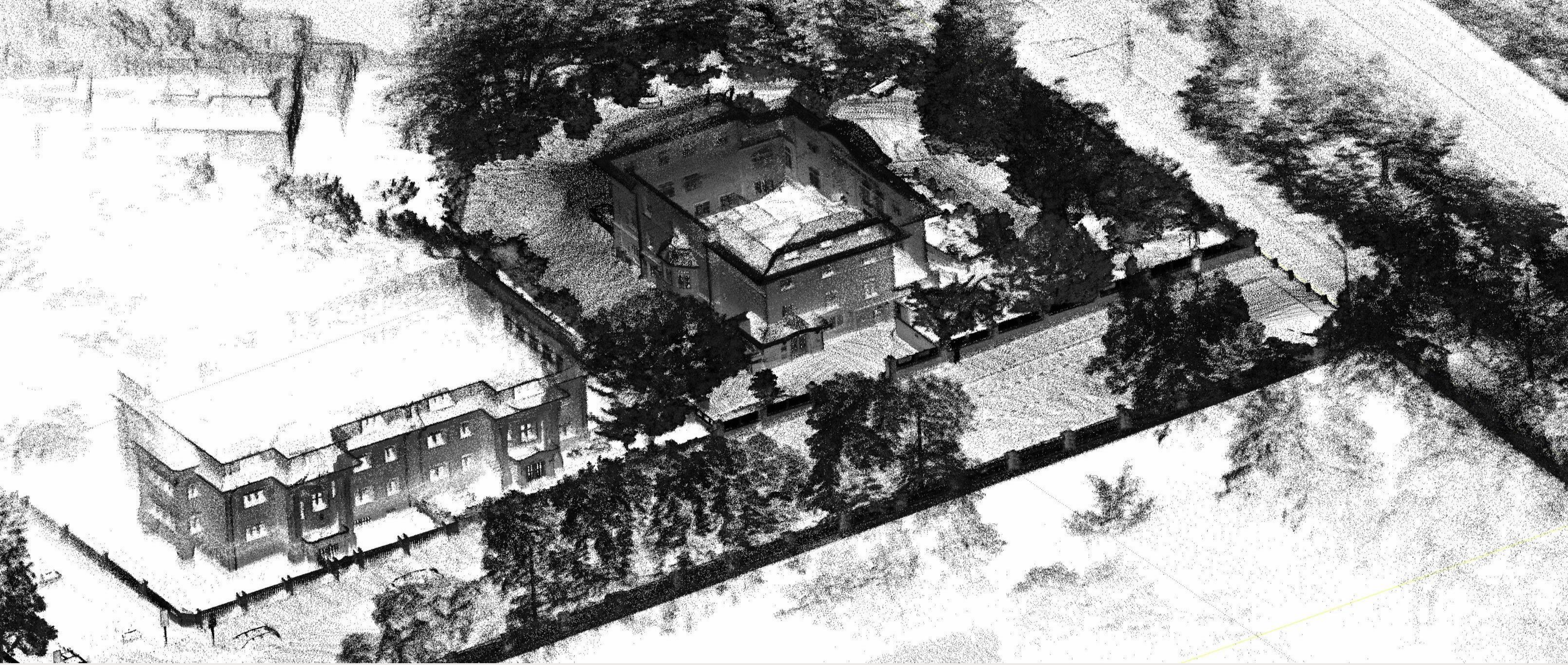
What is LiDAR?





Mobile mapping systems – where can we use LiDAR?



What results can we get?

https://github.com/MapsHD/HDMapping

The main goal of this project

Hardware

The Insta X4 camera has its own time system represented as frames, and synchronization will be performed for 8K 30fps.

Hardware

Timestamp, the link between the laser and the camera.

Hardware

The laser (LIVOX MID-360) has its own timestamp system.

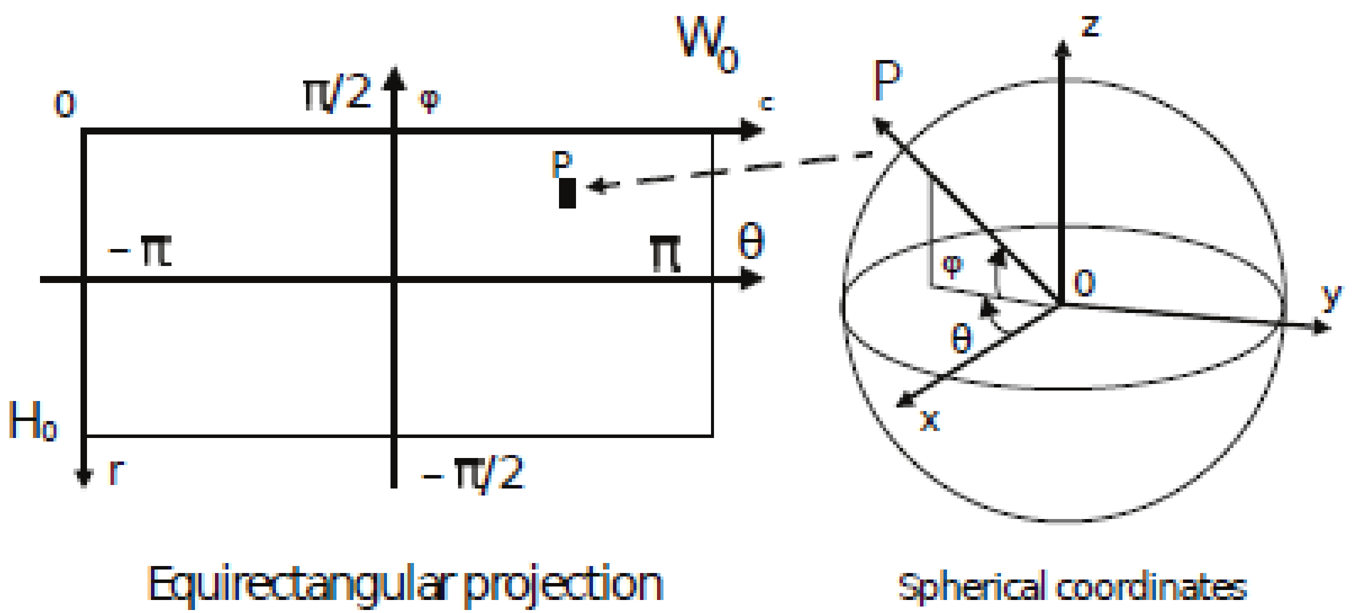
Integrated Synergy System

Complete Setup and Final Result

https://github.com/MapsHD/HDMapping

Top view

Equirectangular Camera Calibration



Colinearity observation equation

$$P^l = [R,t]_{cw} P^g = [R,t]_{wc}^{-1} P^g \tag{1}$$

$$P^l = \begin{bmatrix} p_x^l \\ p_y^l \\ p_z^l \end{bmatrix} \tag{2}$$

$$\left\| P^l \right\| = \sqrt{{p_x^l}^2 + {p_y^l}^2 + {p_z^l}^2} \tag{3}$$

$$P_{r=0}^l = \begin{bmatrix} \frac{p_x^l}{\|P^l\|} \\ \frac{p_y^l}{\|P^l\|} \\ \frac{p_z^l}{\|P^l\|} \end{bmatrix} \tag{4}$$

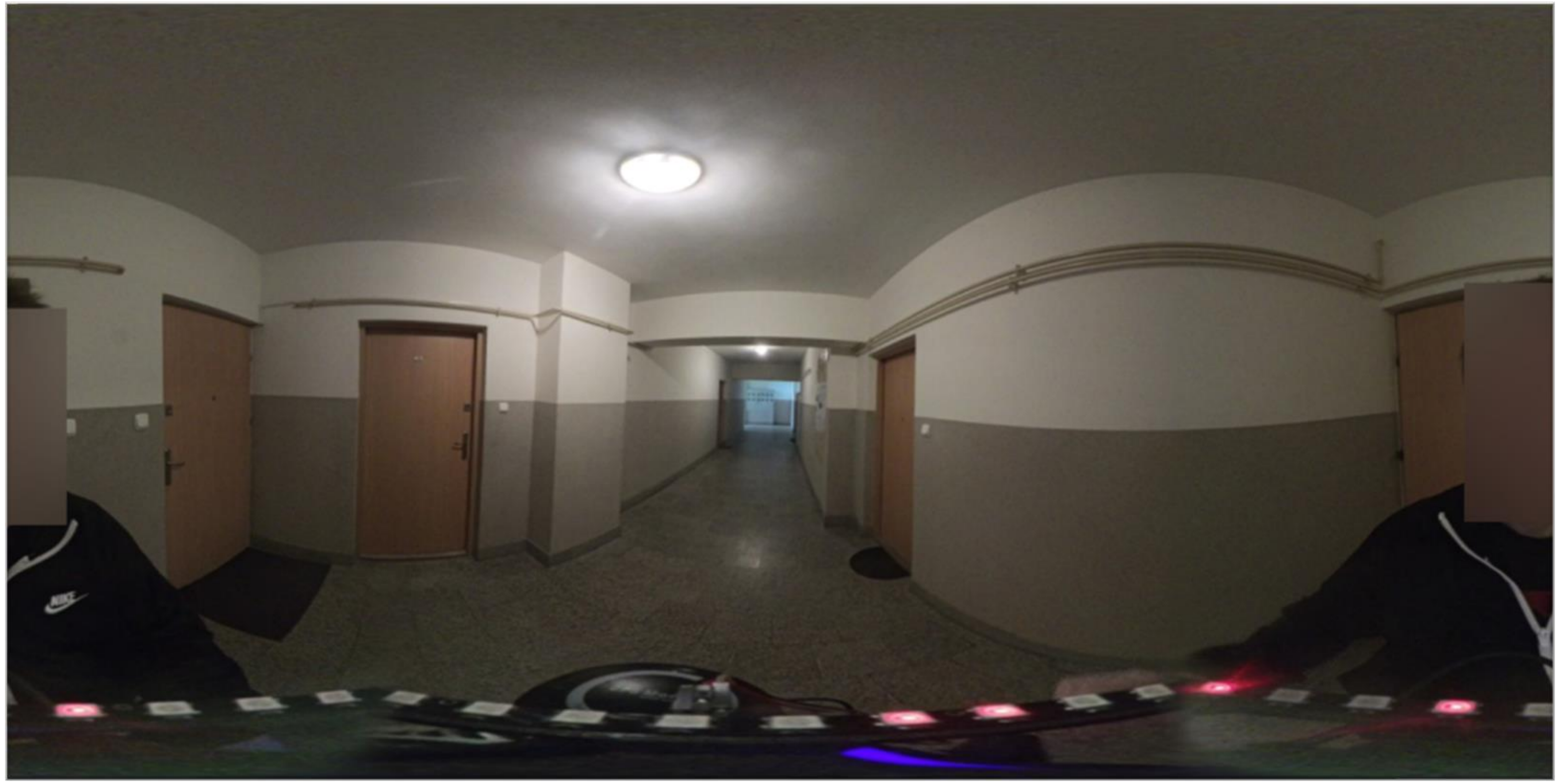
$$\begin{bmatrix} latitude \\ longitude \end{bmatrix} = \begin{bmatrix} -asin(\frac{p_y^l}{\|P^l\|}) \\ atan(\frac{\frac{p_x^l}{\|P^l\|}}{\frac{p_z^l}{\|P^l\|}}) \end{bmatrix} \tag{5}$$

$$\Psi_{[\beta]} = \begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} cols(0.5 + \frac{lon}{2\pi}) \\ rows(0.5 - \frac{lat}{\pi}) \end{bmatrix} \tag{6}$$

$$\min_{[R,t]_{wc}} \sum_{i=1}^{C} \left(\left[u^{kp}, v^{kp} \right]^{\mathsf{T}} - \Psi_{[\beta]}([R,t]_{wc}, x^g, y^g, z^g) \right)^2 \tag{7}$$

$$\underbrace{\begin{bmatrix} u_\delta \\ v_\delta \end{bmatrix}}_{residuals} = \underbrace{\begin{bmatrix} u^{kp} \\ v^{kp} \end{bmatrix}}_{target\ values} - \underbrace{\Psi_{[\beta]}([R,t]_{wc}, x^g, y^g, z^g)}_{model\ function} \tag{8}$$

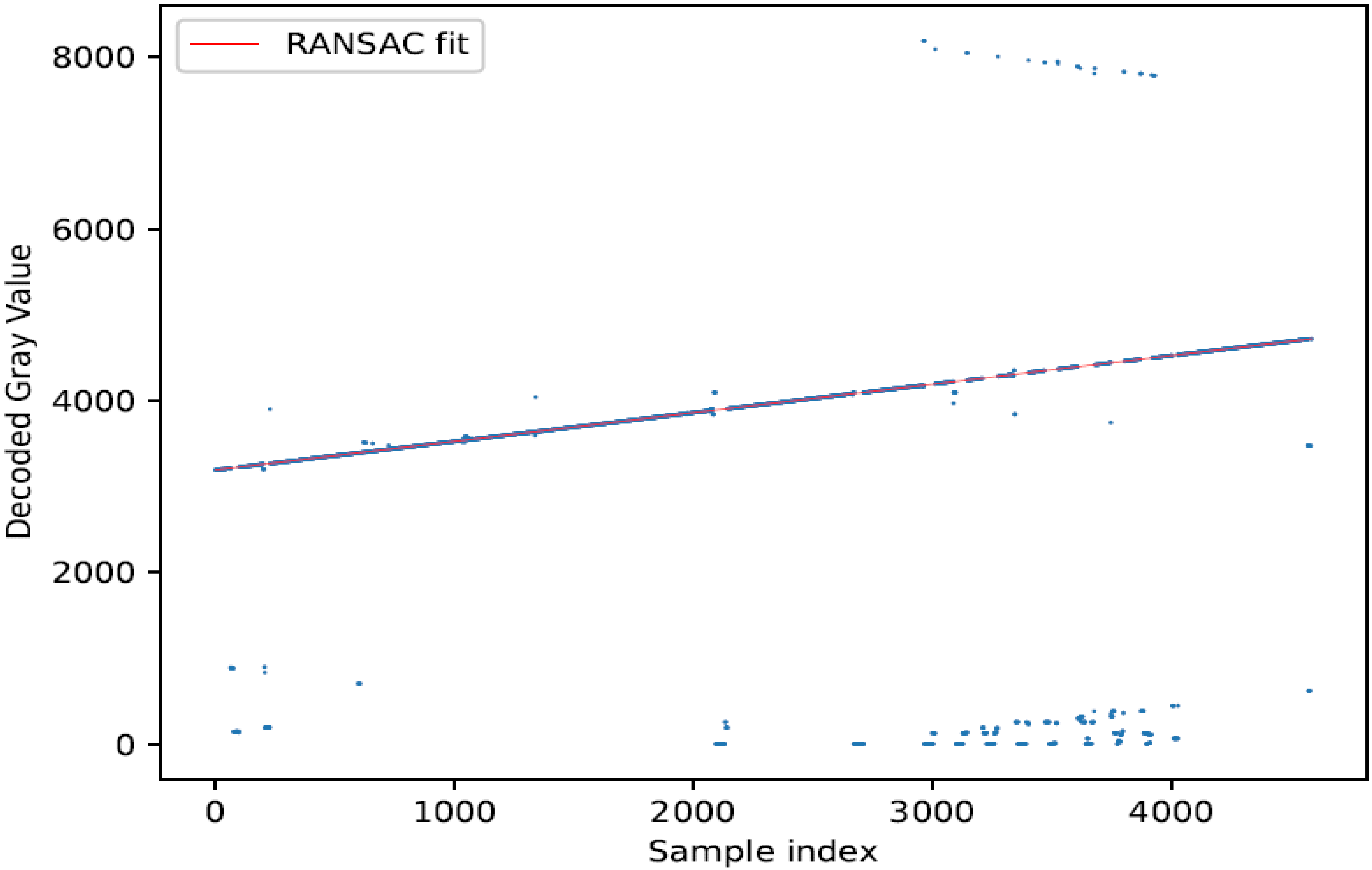
Diodes from an equirectangular image - synchronization

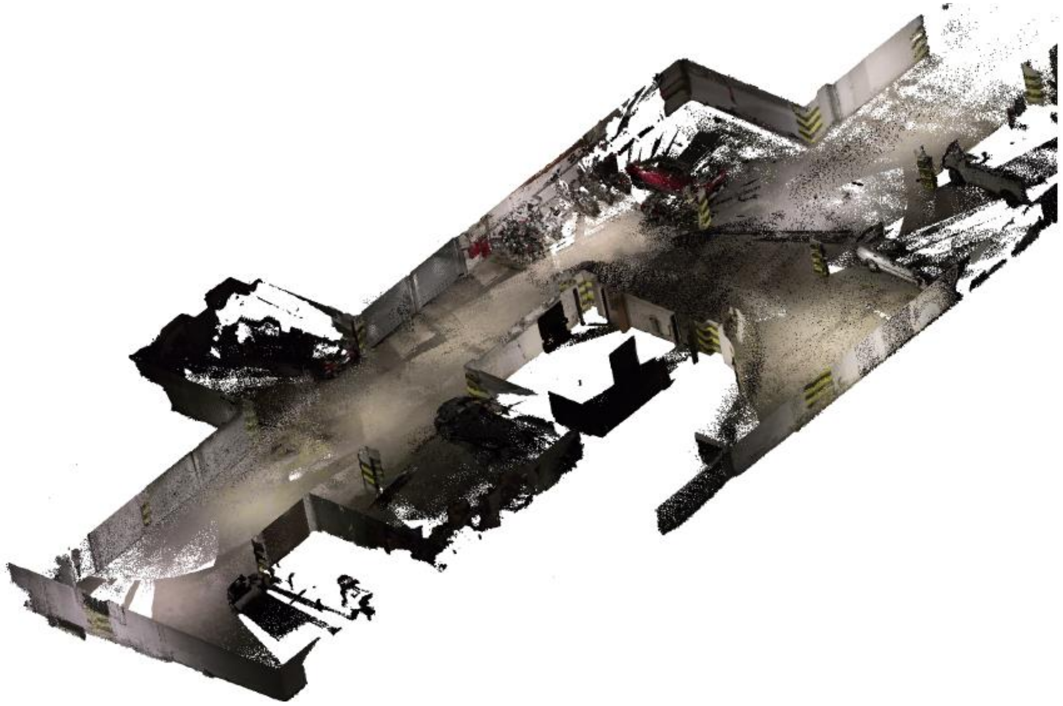


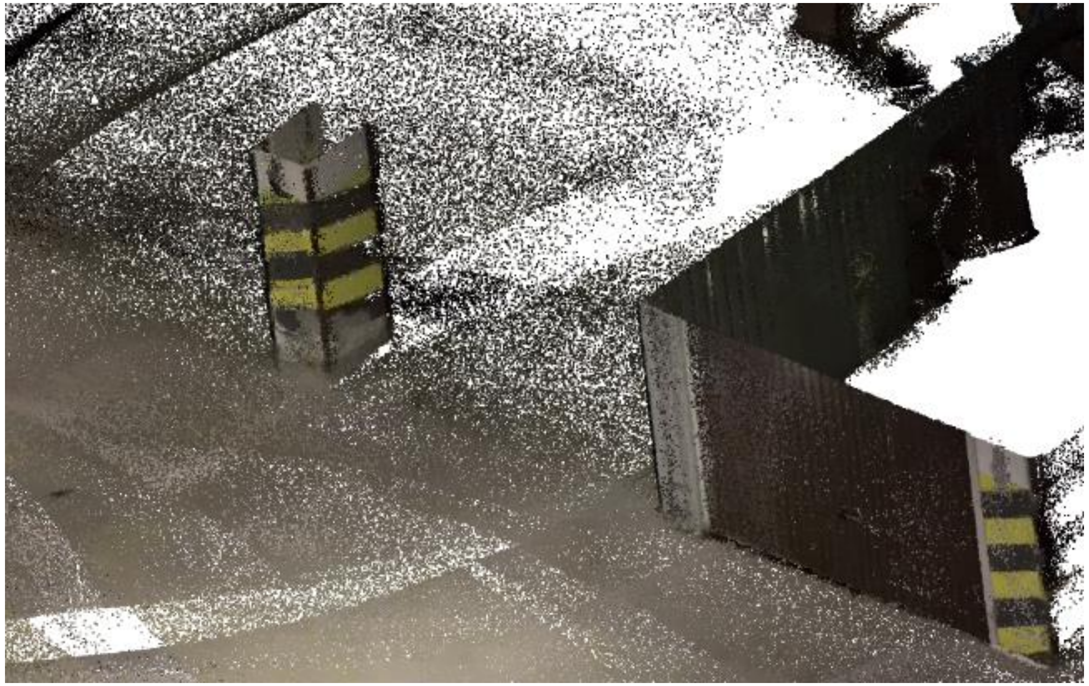
The LED diode ring enables encoding of the timestamp using Gray code, allowing synchronization of the LiDAR and camera with a resolution of 100 ms.

How synchronization is done - an automated system that detects both turned-on and turned-off LEDs.

- ResNet-18 binary classifier (White box – LED not active, red box – LED active) – but not always perfect.
- Attempts with Hough Circle.

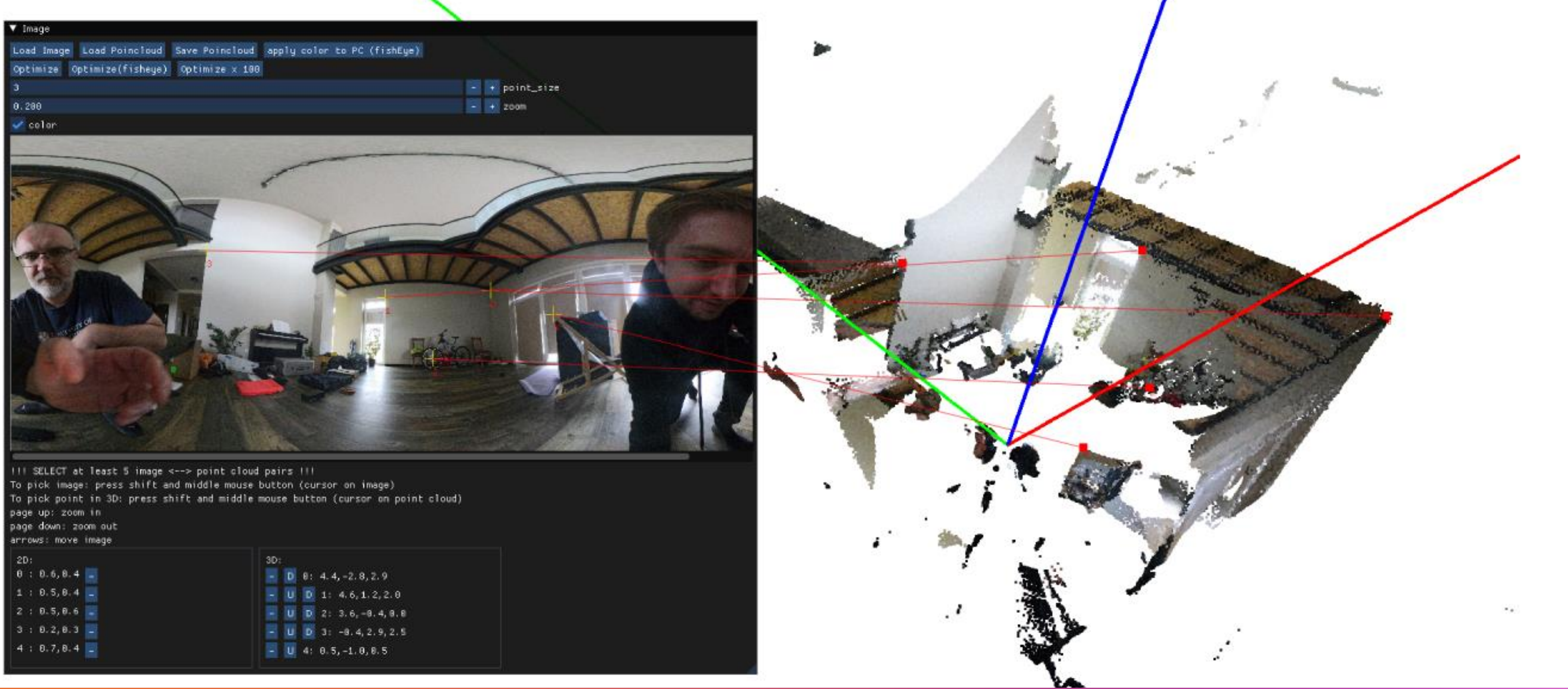

RANSAC fit
8000
6000
4000
2000
0
Decoded Gray Value
0
1000
2000
3000
4000
Sample index





Coloring

Result: Thanks to the integration, we can know our position at any given time. The image, point cloud, and timestamp allow us to colorize the point cloud.



Coloring

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Future Work

Most significant drawback of our solution is the complexity of the procedure. We are going to automatize the colorizing step, thus overall pipeline will be simplified

Gauss Splatting in VR - Colored Point Cloud and Realistic Rendering

End

- https://github.com/MapsHD/HDMapping
- https://www.youtube.com/@MapsHD-HDMapping