Supplementary Material: Privacy Preserving Visual SLAM

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1 Overview

This document is to provide a supplementary description of the main paper, especially concerning the quantitative and qualitative evaluation of our experimental results in Sections 4.4 and 4.5. Additionally, visual materials such as trajectory figures and maps illustrate the results for comparative analysis among the tested datasets or applied methods.

2 Dataset Details

Tables 1 and 2 show the details of the CARLA and KITTI datasets for quantitative evaluation in the main paper (Sec. 4.4), respectively. Table 3 shows the details of the Campus dataset (Scene A, B) and the Desk dataset for qualitative evaluation (Sec. 4.5). Figures 1 and 2 show sample images of the CARLA and Campus datasets, respectively.

Table 1. CARLA dataset for quantitative evaluation

	Image size		
Sequence pair #	Perspective	Fisheye	Equirectangular
#01	640 × 360	N/A	N/A
#02 – 12	1280 × 720	1280 × 720	2160 × 1080

Length (Sequence 1 / 2)			
#01	#02	#03	#04
1m07s / 1m04s	2m20s / 1m16s	2m08s / 1m28s	1m40s / 1m49s
#05	#06	#07	#08
2m11s / 1m34s	2m47s / 1m34s	2m20s / 2m00s	2m21s / 2m04s
#09	#10	#11	#12
2m26s / 1m58s	2m45s / 3m46s	2m56s / 2m53s	2m23s / 2m17s

* The authors assert equal contribution and joint first authorship.

Table 2. KITTI dataset for quantitative evaluation

Sequence pair	Image size	Length (Sequence 1 / 2)
#00	1246 × 376	1m15s / 6m18s
#05	1226 × 370	1m20s / 3m16s

Table 3. Campus dataset (Scene A, B) and Desk dataset for qualitative evaluation

	Image size		
Dataset	Perspective	Fisheye	Equirectangular
Scene A	1920 × 1080	1920 × 1080	1920 × 960
Scene B	1920 × 1080	1920 × 1080	1920 × 960
Desk	960 × 540	N/A	N/A

	Length (Sequence 1 / 2)		
Dataset	Perspective	Fisheye	Equirectangular
Scene A	5m13s / 5m55s	5m29s / 5m42s	4m47s / 5m00s
Scene B	3m23s / 2m44s	2m23s / 2m19s	1m48s / 1m51s
Desk	3m14s / 3m13s	N/A	N/A

(a) Perspective (b) Fisheye (c) Equirectangular

Fig. 1. Sample images of the CARLA dataset. The three images in each row show the same scene with different projection models (perspective, fisheye, equirectangular).

(a) Perspective (b) Fisheye (c) Equirectangular

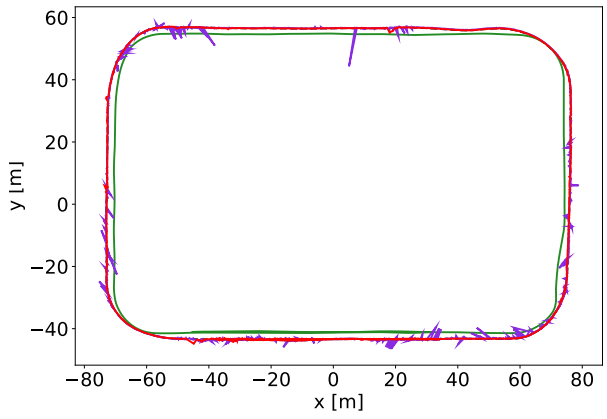
Fig. 2. Sample images of the Campus dataset (top: Scene A, bottom: Scene B).

3 Additional Results

Figure 3 shows the trajectories of the CARLA dataset for evaluation of the tracking time in the main paper. Figures 4 and 5 show the trajectories of the CARLA and KITTI datasets for evaluation of the localization accuracy. Figure 6 shows the trajectories of the CARLA dataset for evaluation of the effectiveness of the global bundle adjustments.

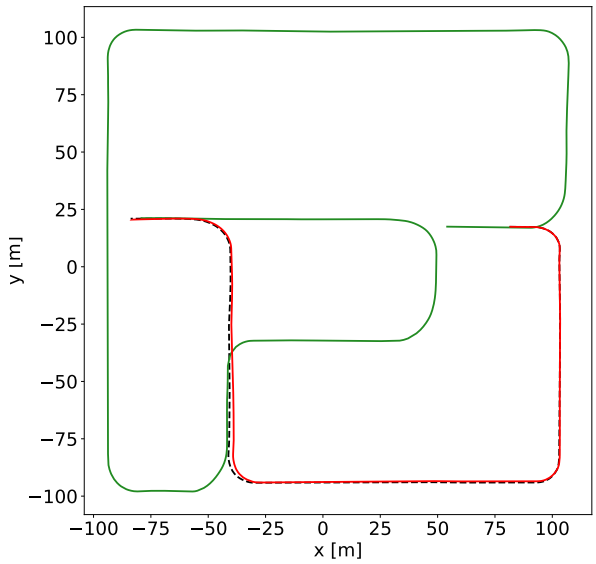
Figure 7 shows an example of the tracking and mapping behavior of LC-VSLAM for the privacy protection on the Desk dataset: (a) scene for prebuilt map where personal objects exist (Sequence 1), (b) scene for LC-VSLAM where the personal objects have been removed (Sequence 2), (c) a point cloud reconstructed from the video of the Sequence 1 with a standard point-based Visual SLAM, (d) a line cloud converted from the point cloud, and (e) mixed line and point clouds after tracking by LC-VSLAM. The 3D points of the concealed privacy objects are not restored near the corresponding 3D lines.

Figures 8 and 9 show all the results of the Campus dataset for the three projection models (perspective, fisheye and equirectangular). The blue lines and the black points show the prebuilt line cloud and the reconstructed point cloud by LC-VSLAM, respectively. The green and red frames show the keyframes. The order from the first (left) to the last (right) columns represents examples of the reconstruction process.

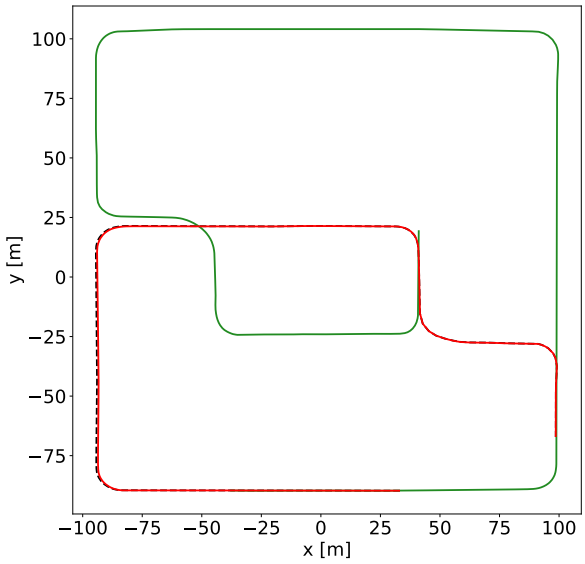


(a) Sequence pair #01 of the CARLA dataset (Perspective projection model)

Fig. 3. Trajectories on the CARLA dataset for evaluation of the tracking time: estimated by LC-VSLAM (red), estimated by p6L (violet), ground truth (black), and prebuilt map (green).



(a) Sequence pair #02 of the CARLA dataset (Perspective projection model)



(b) Sequence pair #03 of the CARLA dataset (Perspective projection model)

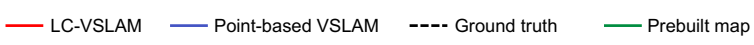
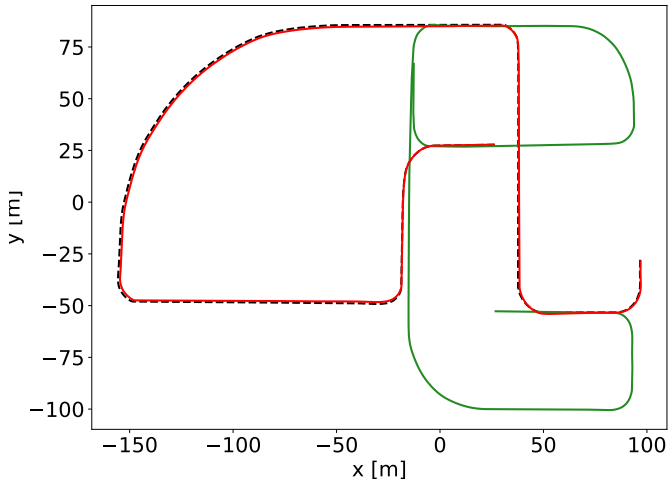
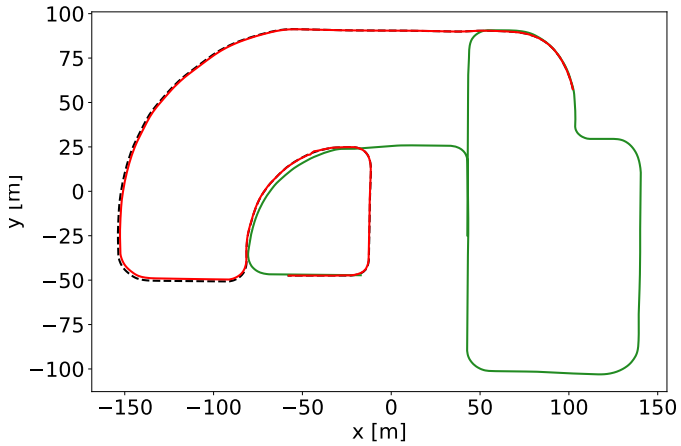


Fig. 4. Trajectories of the CARLA dataset (Sequences #02 and #03). For the evaluation of the localization accuracy: estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (green).



(c) Sequence pair #04 of the CARLA dataset (Fisheye projection model)



(d) Sequence pair #05 of the CARLA dataset (Perspective projection model)

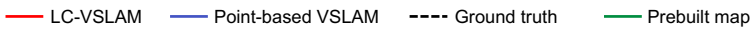
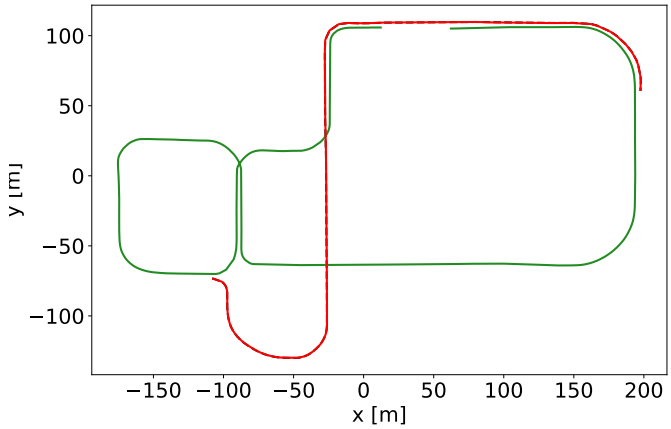
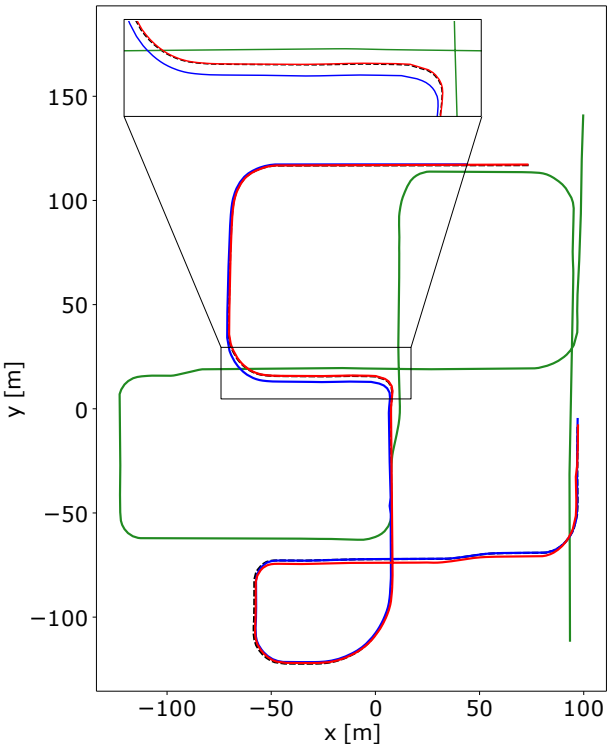


Fig. 4. Trajectories of the CARLA dataset (Sequences #04 and #05). For the evaluation of the localization accuracy: estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (green).



(e) Sequence pair #06 of the CARLA dataset (Equirectangular projection model)



(f) Sequence pair #07 of the CARLA dataset (Perspective projection model)

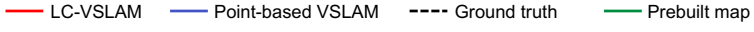
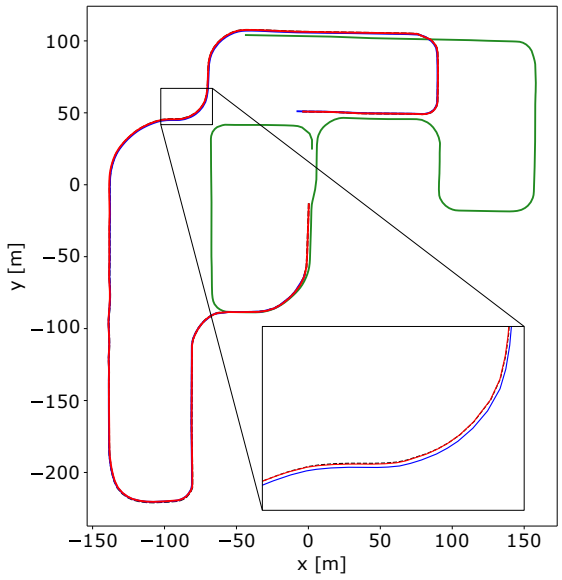
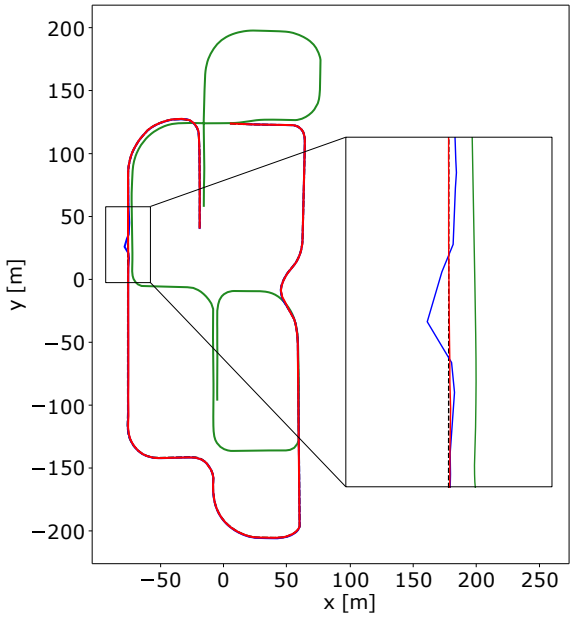


Fig. 4. Trajectories of the CARLA dataset (Sequences #06 and #07). For the evaluation of the localization accuracy: estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (green).



(g) Sequence pair #08 of the CARLA dataset (Equirectangular projection model)



(h) Sequence pair #09 of the CARLA dataset (Fisheye projection model)

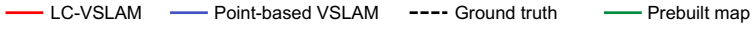
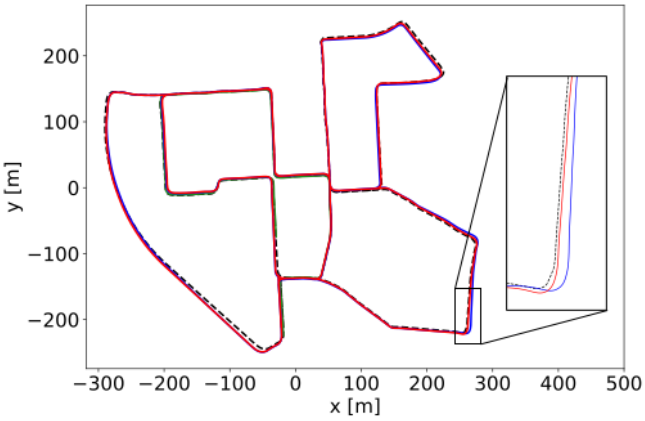
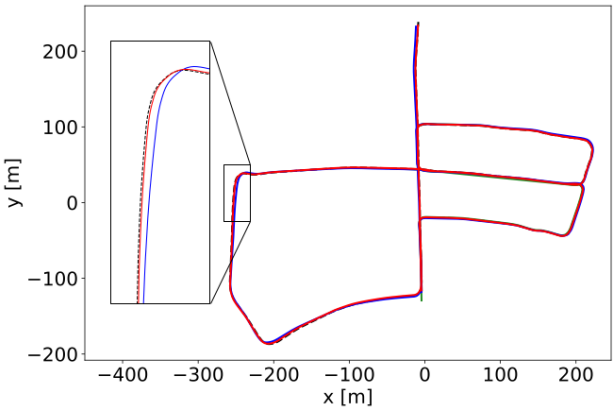


Fig. 4. Trajectories of the CARLA dataset (Sequences #08 and #09). For the evaluation of the localization accuracy: estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (green).



(a) Sequence pair #00 of the KITTI dataset



(b) Sequence pair #05 of the KITTI dataset

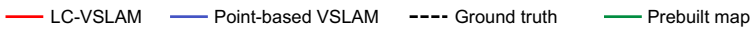
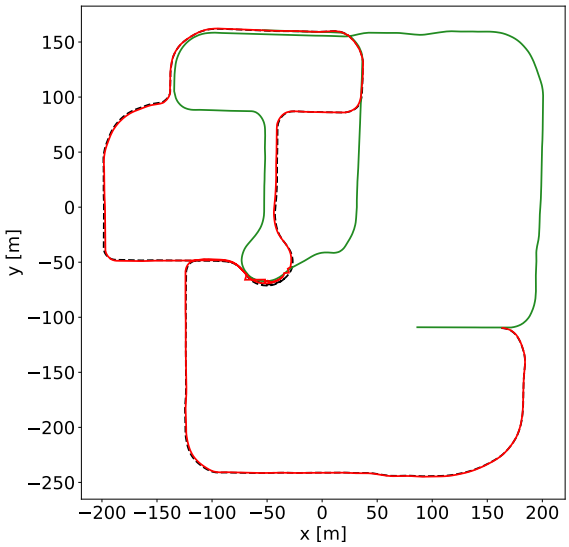
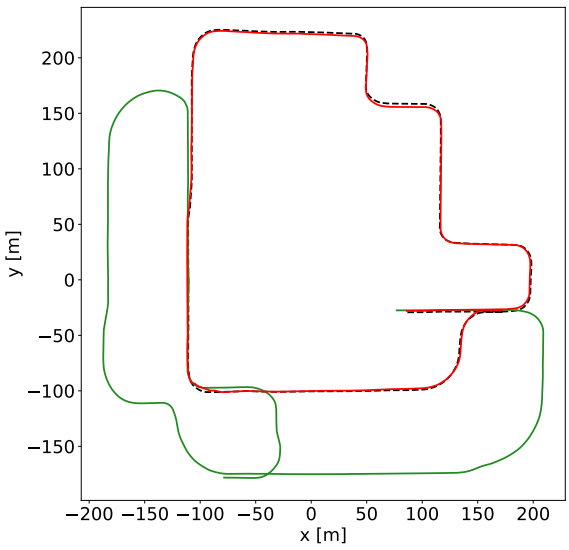


Fig. 5. Trajectories of the KITTI dataset (Sequences #00 and #05). For the evaluation of the localization accuracy: estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (green).



(a) Sequence pair #10 of the CARLA dataset (Fisheye projection model)



(b) Sequence pair #11 of the CARLA dataset (Fisheye projection model)

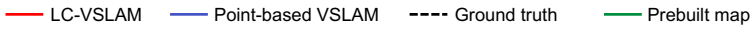
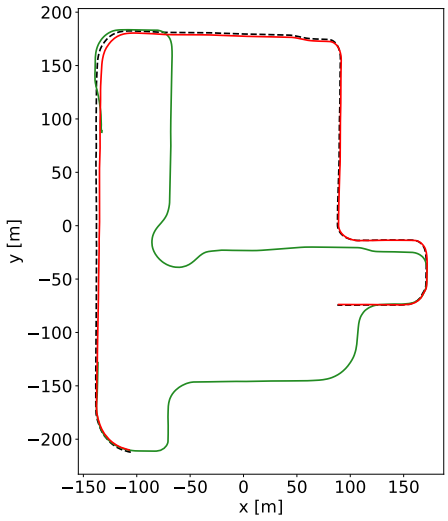


Fig. 6. Trajectories of the CARLA dataset (Sequences #10 and #11). For evaluation of the effectiveness of the global bundle adjustments : estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (blue).



(c) Sequence pair #12 of the CARLA dataset (Fisheye projection model)

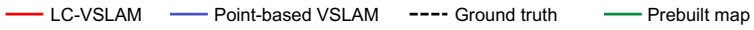
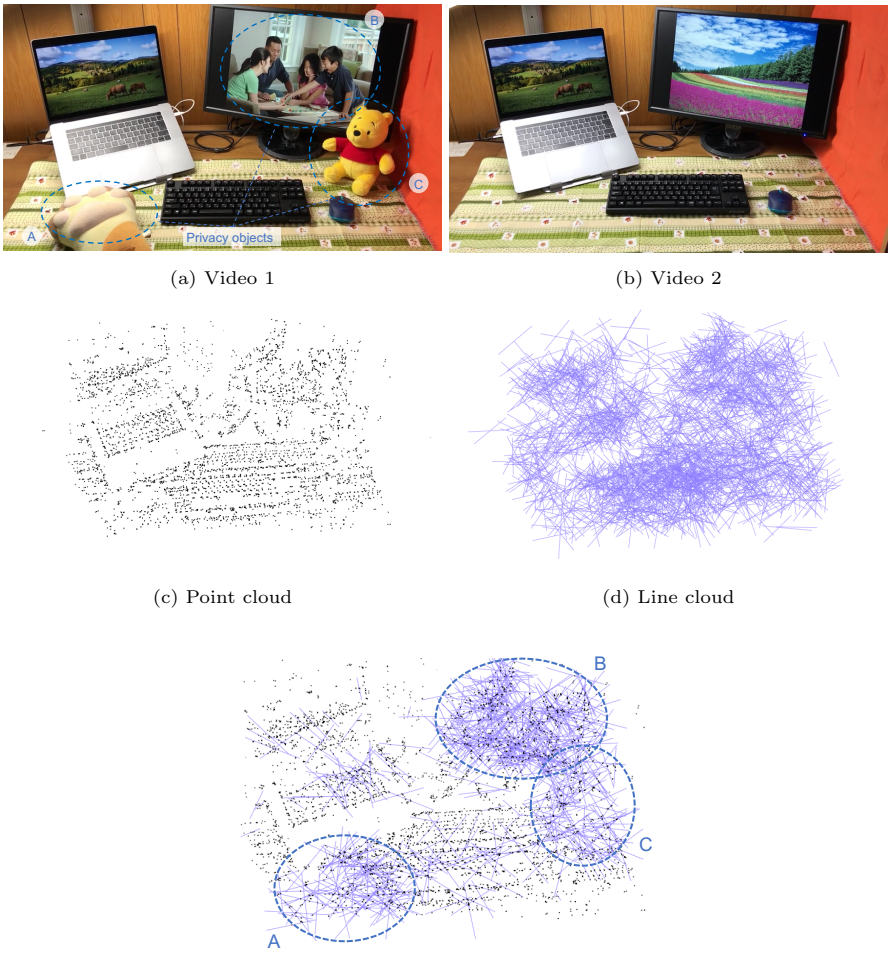


Fig. 6. Trajectories of the CARLA dataset (Sequence #12). For evaluation of the effectiveness of the global bundle adjustments : estimated by LC-VSLAM (red), estimated by a standard Visual SLAM with a point-cloud prebuilt map (blue), ground truth (black), and prebuilt map (blue).



(a) Video 1

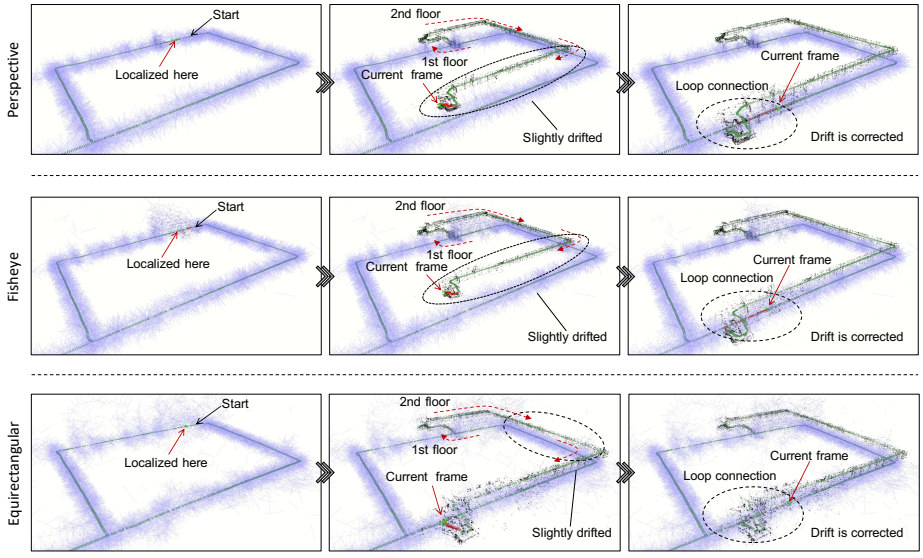
(b) Video 2

(c) Point cloud

(d) Line cloud

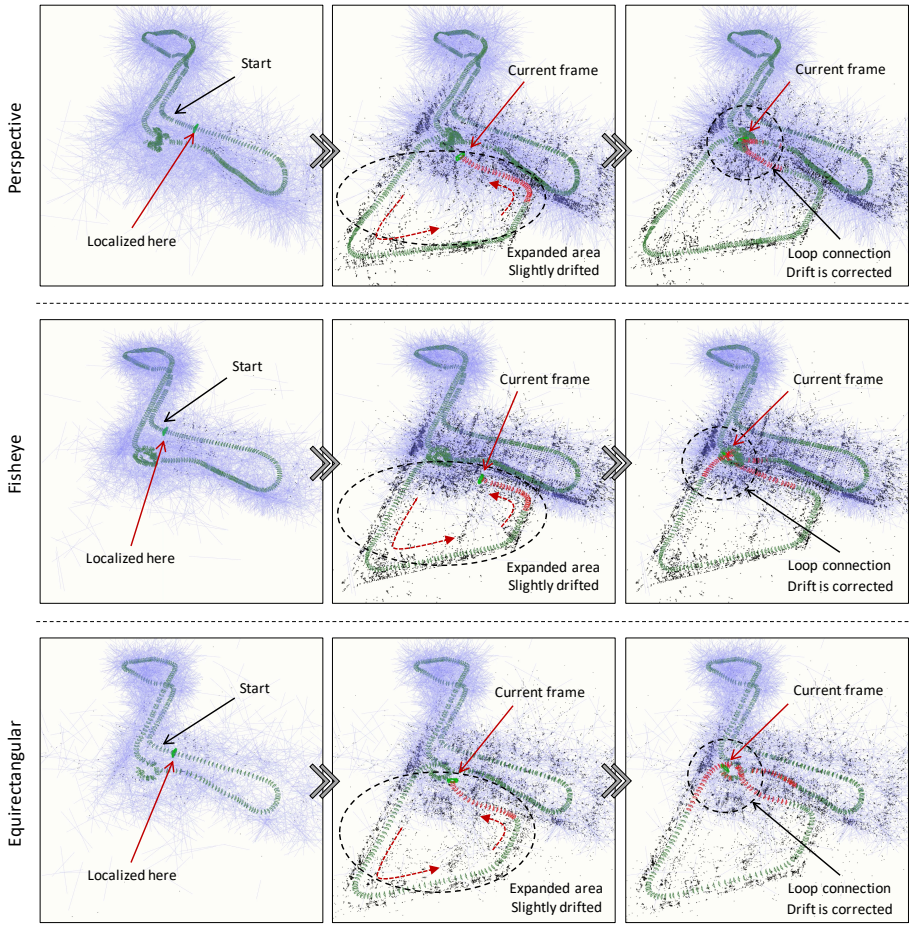
(e) Mixed line and point clouds

Fig. 7. Tracking and mapping behavior of LC-VSLAM for privacy protection on the Desk dataset: (a) scene for prebuilt map where personal objects exist (Video 1), (b) scene for LC-VSLAM where the personal objects have been removed (Video 2), (c) a point cloud reconstructed from Video 1 with a standard point-based Visual SLAM, (d) a line cloud converted from the point cloud, and (e) mixed line and point clouds after tracking by LC-VSLAM. It should be noted here that the 3D points of the concealed privacy objects are not restored near the corresponding 3D lines.



(a) Relocalization (b) Before loop closure (c) After loop closure

Fig. 8. Behavior of relocalization, tracking, local and global mapping for each projection model on the Scene A of the Campus dataset: (a) relocalization, (b) drifted and (c) corrected trajectories before and after loop closure.



(a) Relocalization (b) Before loop closure (c) After loop closure

Fig. 9. Behavior of relocalization, tracking, local and global mapping for each projection model on the Scene B of the Campus dataset: (a) relocalization, (b) drifted and (c) corrected trajectories before and after loop closure.