Supplementary Material: Infrastructure-based Multi-Camera Calibration using Radial Projections

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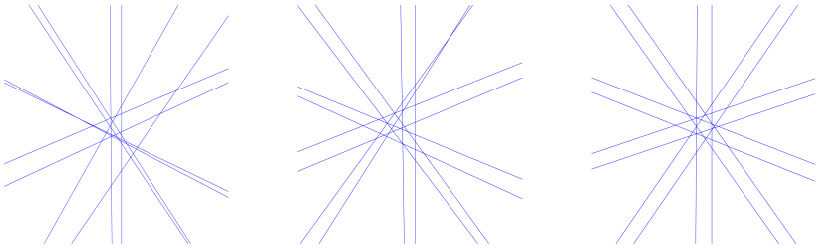
1 Error Analysis for the Individual Steps

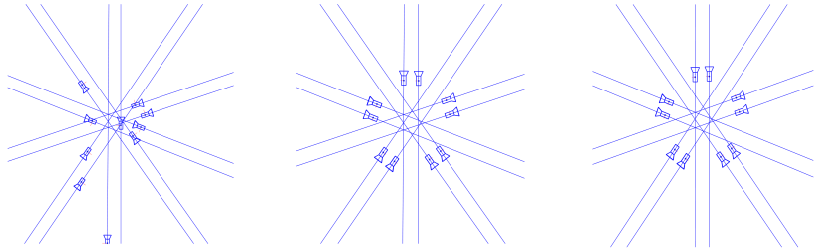
To further analyze each step of the calibration pipeline, we calculate the (radial) reprojection error for each step and show that it actually improves the results. Table 1 shows the average error for each step of calibrating the pentagonal camera rig for one of the outdoor dataset used in the main paper. The map used in this dataset is shown in Figure 2. In the first three steps we measure the radial reprojection error as the poses are represented with the radial camera model as described in Section 2.4 of the main paper, and the intrinsic parameters are still unknown. During each of these steps the radial reprojection error decreases significantly, especially after the bundle adjustment for the radial cameras. After the camera upgrading, we obtain the intrinsics and it becomes possible to compute the normal (2D) reprojection error. The decreasing error shows that each step in our calibration pipeline helps to refine the results. The plot of the extrinsics for each step is shown in Figure 1. From the figure we can see that the extrinsic parameters of the rig are already quite close to the optima before the non-linear refinement in the final step.

Table 1. Error analysis for each step of the calibration pipeline For the first three steps the reported error is the average radial reprojection error. For the next three steps, the error is the average 2D reprojection error in pixels.

	Reprojection error (px)	
	Radial	2D
1. Radial camera rig initial guess	13.08	-
2. Radial camera rig pose optimization Eq.(5)	11.54	-
3. Radial camera rig pose refinement Eq.(6)	0.74	-
4. Camera upgrade (intrinsic est.)	-	3.37
5. Camera upgrade optimization Eq.(9)	-	1.73
6. Final refinement Eq.(10)	-	0.98



(a) Step 1 (b) Step 2 (c) Step 3



(d) Step 4 (e) Step 5 (f) Step 6

Fig. 1. Extrinsics plot for each step. The step definition is in Table 1. The first row represents the step No.1-3 where the cameras are modeled as 1D radial camera. The second row represents the step No.4-6.

References

1. Schonberger, J.L., Frahm, J.M.: Structure-from-motion revisited. In: Computer Vision and Pattern Recognition (CVPR) (2016)

Fig. 2. Experiments in outdoor urban environment. *Top:* The sparse reconstruction from COLMAP [1]. Frames captured by Gopro helmet for mapping shown in red. *Middle:* The same scene with frames used for calibration in red captured by pentagonal camera rig. *Bottom:* Aerial view of scene.