ASSIGNMENT 6

15663 Computational Photograpy Fall 2023
DUE: December 08, 2023

1 Implementing structured-light triangulation (100 points)

1.1 Video processing (25 points)

Per-frame shadow edge estimation For each frame t, you need to estimate the lines $\lambda_h(t)$ and $\lambda_v(t)$, running along the right shadow edges on the unobstructed horizontal and vertical planar regions, respectively.

For the vertical planar region, we chose $(250, 0)$ as the upper-left corner and $(800, 300)$ as the bottom-right corner. For the horizontal planar region, we chose $(200, 660)$ as the upper-left corner and $(830, 768)$ as the bottom-right corner. The regions are shown below:

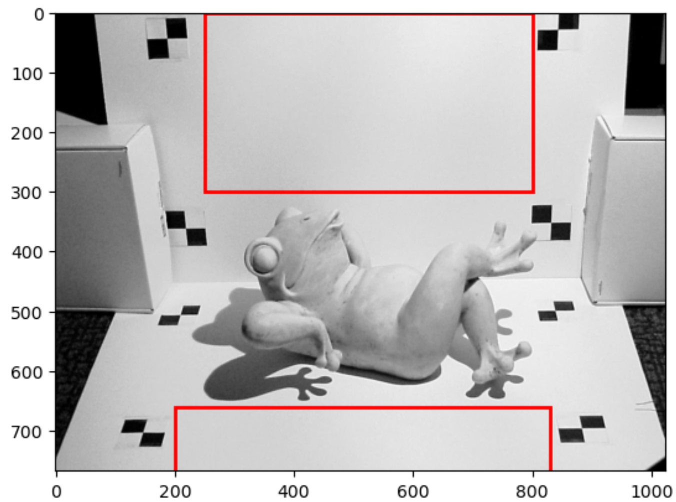

Figure 1: Per-frame shadow edge estimation. The unobstructed horizontal and vertical planar regions are marked with the red rectangles.

Visualization of the shadow edge estimates:

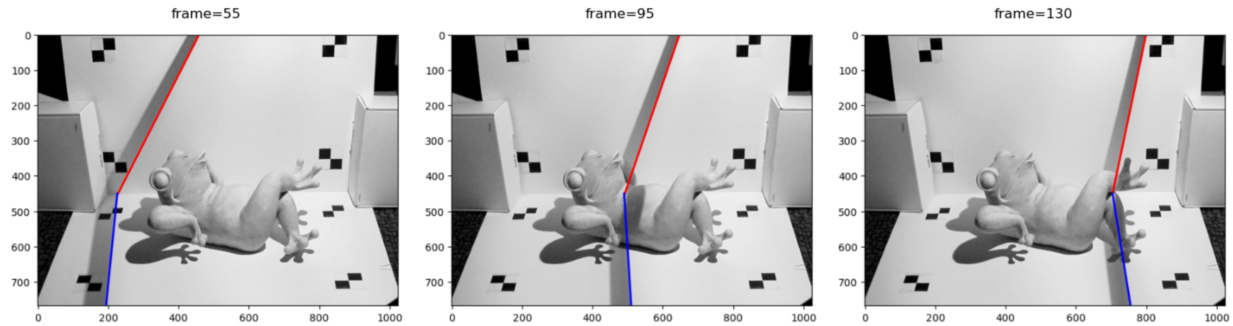

Figure 2: Per-frame shadow edge estimation

Per-pixel shadow time estimation To perform 3D reconstruction, you need to also estimate the per-pixel shadow times. For each pixel (x, y), you can estimate its shadow time $t_{shadow}(x, y)$ by finding the zero-crossing of the difference image $\Delta I(x, y, t)$ as a function of time t.

Visualization of the per-pixel shadow time estimates:

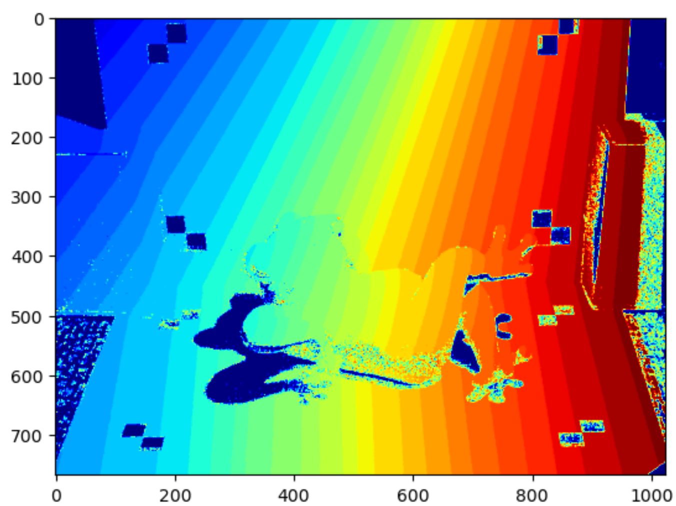

Figure 3: Per-pixel shadow time estimation

2 Intrinsic and extrinsic calibration (50 points)

Intrinsic calibration The resulting camera intrinsic parameters are saved in `./result/camera/intrinsic_calib.npz`.

Calibration of ground planes The resulting camera extrinsic parameters are save in `./result/camera/extrinsic_calib.npz`.

Calibration of shadow lines The 3D points $P1$, $P2$, $P3$ and $P4$ are saved in `./result/camera/reconstructed_points.npz`.

Calibration of shadow planes The estimated shadow plane parameters ($P1$ and $\hat{n}$ are saved in `./result/camera/shadow_planes.npz`

2.1 Reconstruction (25 points)

First, crop the part of the image you want to reconstruct. Then, for each pixel $p = (x, y)$ in this rectangle, fetch its shadow time $t_{shadow}(x, y)$. Next, fetch the shadow plane $S(t_{shadow}(x, y))$ for that frame. Back-project the pixel p into a 3D ray r. Finally, intersect this ray with the shadow plane $S(t_{shadow}(x, y))$. The resulting intersection point P is the reconstructed 3D point corresponding to pixel p.

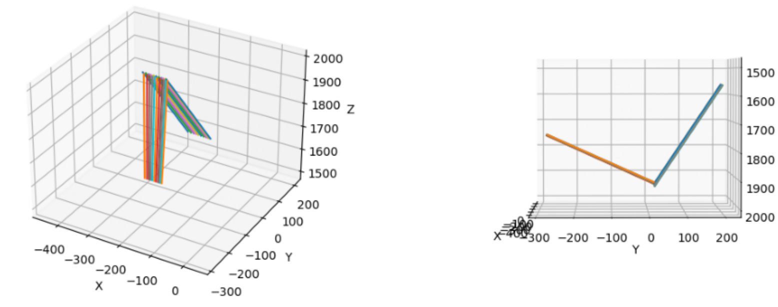

Figure 4: Visualization of the shadow edges in 3D

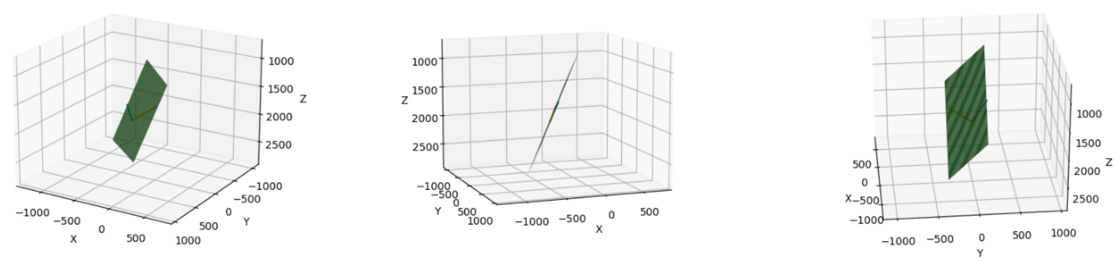

Figure 5: Visualization of the shadow planes in 3D

Repeat this process for all pixels in your cropped image, to recover a 3D point cloud.

The reconstruction results for the frog sequence:

Figure 6: Final reconstruction result

To improve the result, we removed the outliers by only keeping points whose distances to origin are greater than 1750 and less than 2000.

3 Build your own 3D scanner (100 points)

The setup:

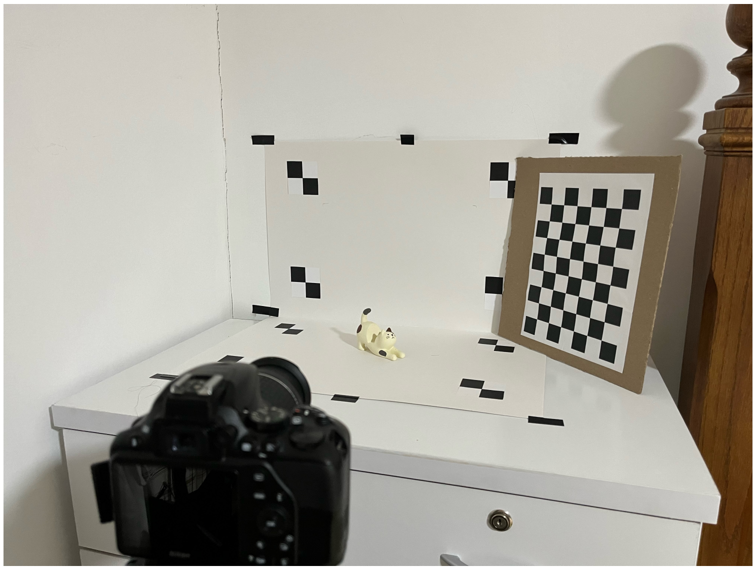

Figure 7: The setup we built

Calibration Firstly, we used the checkerboard pattern to calibrate our own camera.

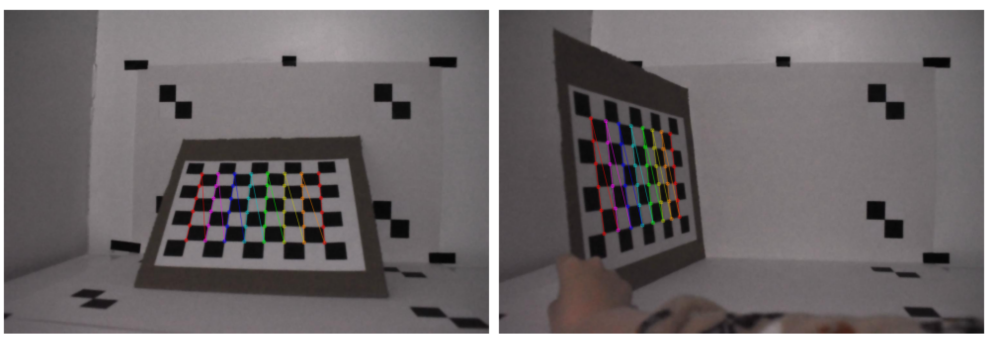

Figure 8: Camera Intrinsics Calibration

The camera extrinsics are calibrated using the checkerboard mark on the corners. The horizontal and vertical calibration are shown below:

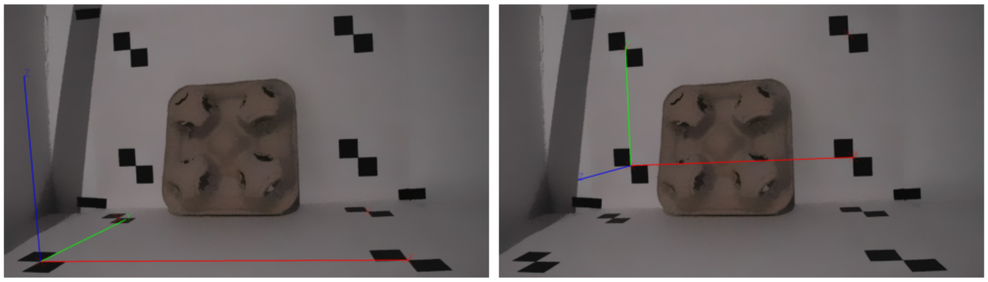

Figure 9: Camera Extrinsics Calibration

Object 1: Slipper The first object is the slipper:

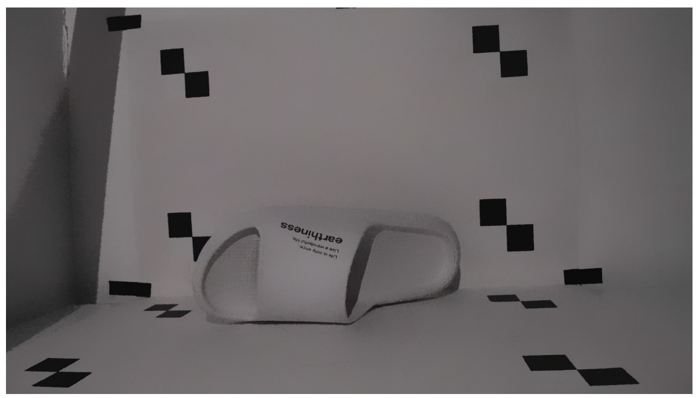

Figure 10: Caption

To extract the shadow edges correctly, we first performed bilateral filtering on all images, with $\sigma_r = 40$ and $\sigma_s = 30$.

The per-pixel shadow time estimation, the visualization of shadow edges and shadow plane:

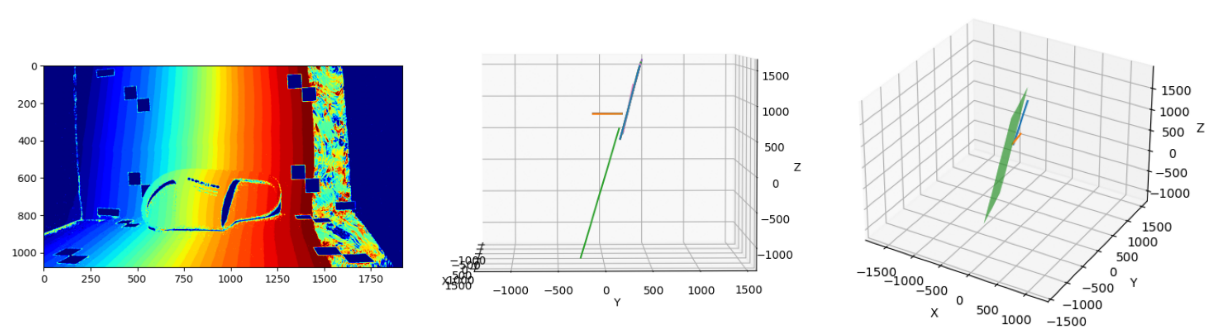

Figure 11: Estimation of per-frame shadow edges and per-pixel shadow times.

We removed the outliers by removing points with $z < 0$ as well as points whose distance to origin is greater than 1000. The reconstruction result:

Figure 12: Caption

Object 2: Cup Holder The first object is the cup holder:

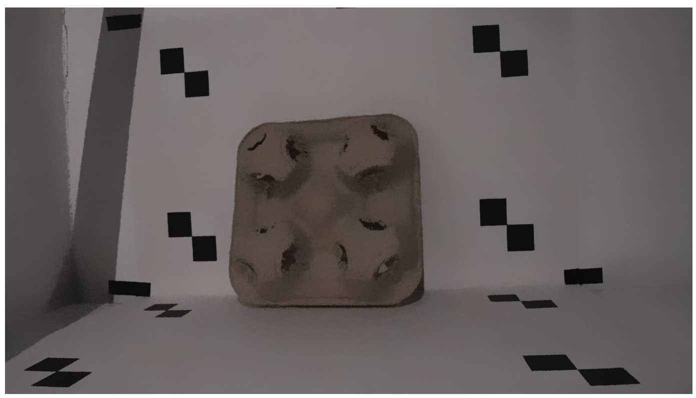

Figure 13: Caption

Similarly, to extract the shadow edges correctly, we first performed bilateral filtering on all images, with $\sigma_r = 40$ and $\sigma_s = 30$.

The per-pixel shadow time estimation, the visualization of shadow edges and shadow plane:

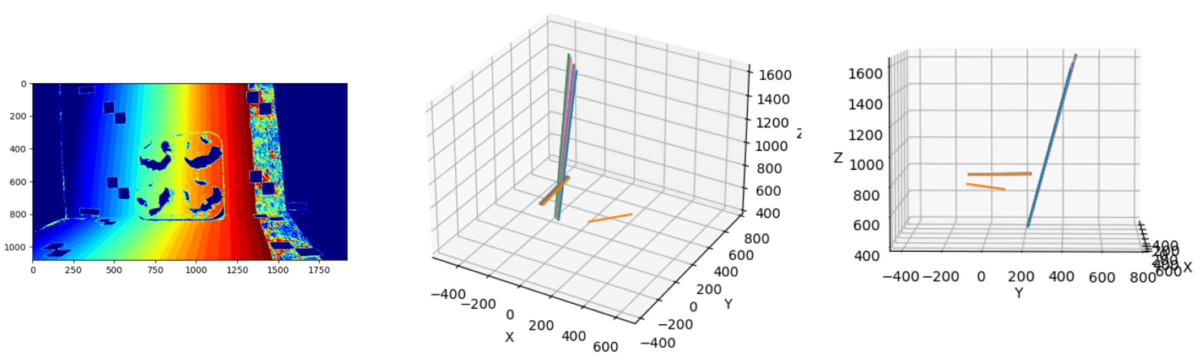

Figure 14: Estimation of per-frame shadow edges and per-pixel shadow times.

We removed the outliers by removing points with $z < 0$ as well as points whose distance to origin is greater than 650. The reconstruction result:

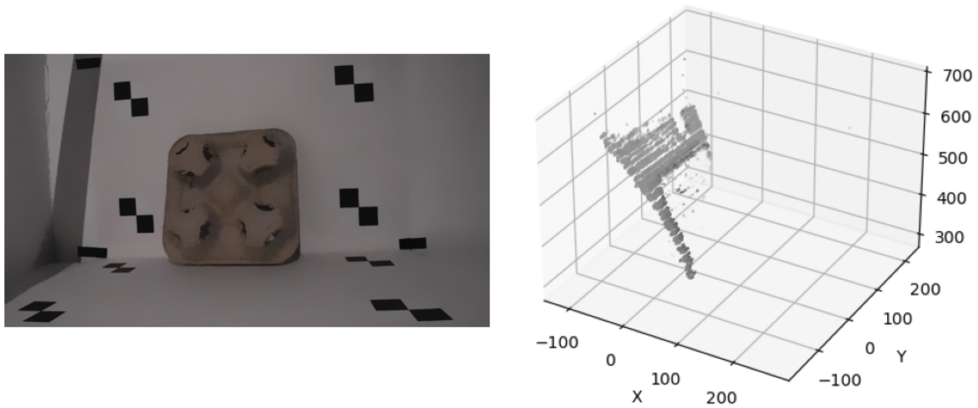

Figure 15: Caption

The reconstruction results still look corrupted. We think that this is mainly caused by the sensor noise which made it hard to correctly detect the shadow edges. The positions of the checkerboard patterns on the four corners of the horizontal and vertical planes might also introduced some error which then affected the reconstruction results.