CSCI 5980 Assignment 2

1 Camera Calibration

The projection matrix is

$$\mathbf{K} = \begin{bmatrix} f & 0 & p_x \\ 0 & f & p_y \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 3351.6 & 0 & 2016 \\ 0 & 3351.6 & 1512 \\ 0 & 0 & 1 \end{bmatrix} \tag{1}$$

where f is the focal length in pixel, $p_x = \frac{w_{img}}{2}$ and $p_y = \frac{h_{img}}{2}$. And $f = 3.99 * 4032/4.8$.

(a) Original image (b) Undistorted image (c) $k > 0$ (d) $k < 0$

Figure 1: Lens distortion recification

To calibrate lens distortion, we use the radial distortion model with a single parameter k_1, and we try to adjust the value of k_1 to find the best undistorted image as Fig. 1b, and k_1 = -0.6.

2 Projective Line

We carefully pick four points that represent two sets of parallel lines and they are $\mathbf{p}_1$, $\mathbf{p}_2$, $\mathbf{p}_3$ and $\mathbf{p}_4$. And the parallel lines are

$$\mathbf{l}_{11} = \mathbf{p}_1 \times \mathbf{p}_2 \tag{2}$$

Same procedure goes for other parallel lines $\mathbf{l}_{12}$, $\mathbf{l}_{21}$ and $\mathbf{l}_{22}$. A vanish point are the intersection of two parallel lines, so the vanish points are

$$\mathbf{x}_1 = \lambda \mathbf{l}_{11} \times \mathbf{l}_{12} \tag{3}$$

where λ is the scale factor that makes the last element of vanish point 1. Same procudure goes for another vanish point $\mathbf{x}_2$. And the vanish line passing vanish points and it's shown as Fig. 2a

$$\mathbf{l}_v = \mathbf{x}_1 \times \mathbf{x}_2 \tag{4}$$

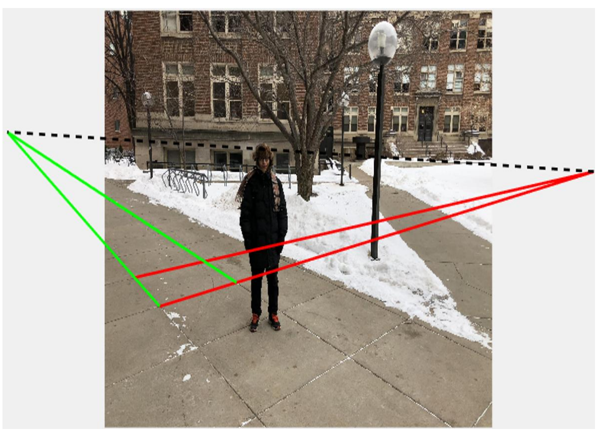
Given two vanish points (in x and y direction) $\mathbf{x}_1$ and $\mathbf{x}_2$, we can compute the rotation matrix $\mathbf{R}_w^c = \begin{bmatrix}\mathbf{r}_1 & \mathbf{r}_2 & \mathbf{r}_3\end{bmatrix}$ as follows

$$\mathbf{r}_1 = \frac{\mathbf{K}^{-1}\mathbf{x}_1}{\|\mathbf{K}^{-1}\mathbf{x}_1\|} \quad \mathbf{r}_2 = \frac{\mathbf{K}^{-1}\mathbf{x}_2}{\|\mathbf{K}^{-1}\mathbf{x}_2\|} \quad \mathbf{r}_3 = \mathbf{r}_1 \times \mathbf{r}_2 \tag{5}$$

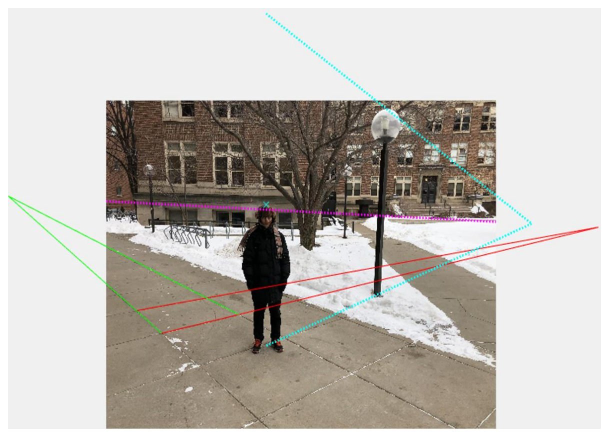
We visualize the rotation matrix in Fig. 2c, which means that we are standing at the left corner and facing the right to take the picture. Then we use the cross ratio as shown in Fig. 2b to compute the height of the lamp given the height of the boy(1.70m). After putting the lamp at the same place of the boy by vanish lines, the height of the lamp is

$$H_{lamp} = H_{boy}\frac{h'_{lamp}h_{\infty}}{h_{boy}h'_{\infty}} \tag{6}$$

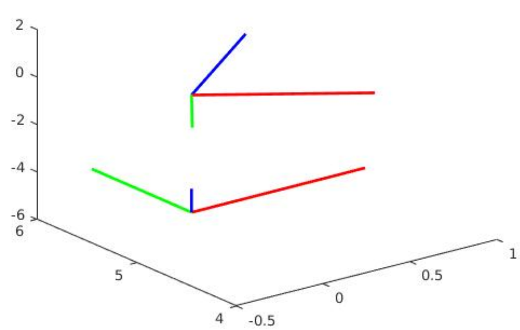
where $h'_{lamp} = 3012.9$, $h_{\infty} = 11860$, $h_{boy} = 1301$, $h'_{\infty} = 13573$, and H_{lamp} is computed as 3.4 m. And the result is acceptable compared to the measurement.
Next to put the image of the panda on the ground, we select four corners on the ground and panda image respectively as match points, and compute the homography based on the match points, then we use the homography (7) to warp the panda image to a new image, as shown in Fig. 2d.



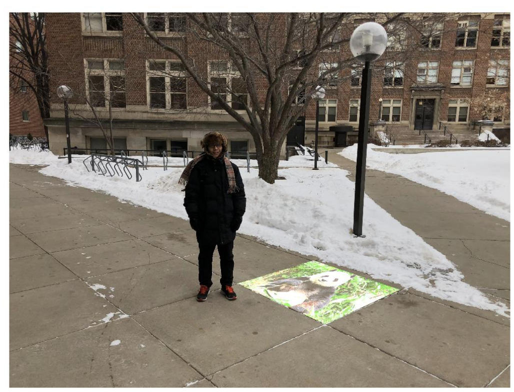
(a) Vanish line



(b) Cross ratio



(c) Camera orientation



(d) Image warpping

Figure 2: Figures of question 2

$$\lambda \begin{bmatrix} v_x \\ v_y \\ 1 \end{bmatrix} = \mathbf{H} \begin{bmatrix} u_x \\ u_y \\ 1 \end{bmatrix} \tag{7}$$

3 Panoramic Image

The direction vector for point (ϕ, h) is

$$\mathbf{p}_{\phi,h} = \begin{bmatrix} f \cos(\phi) \\ h - \frac{H}{2} \\ f \sin(\phi) \end{bmatrix} \tag{8}$$

and thus we can map the plane coordinate to the cylindrical coordinate. Based on the four correspondences, we can compute the homography between two images and thus rotation matrix between two cameras.

$$^{c1}_{c2}\mathbf{R} = \mathbf{K}^{-1}{}^{I1}_{I2}\mathbf{H}\mathbf{K} \tag{9}$$

and based on the rotation rule

$$^{c1}_{c3}\mathbf{R} = {}^{c1}_{c2}\mathbf{R}{}^{c2}_{c3}\mathbf{R} \tag{10}$$

we can find the all rotations respect to the first camera orientation $^{c1}_{i}\mathbf{R}$, and we visualize the camera Z axis in Fig. 3 where the red line is the initial orientation.

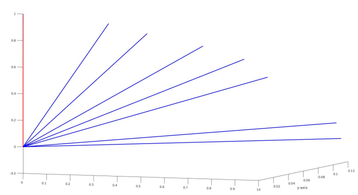


Figure 3: Panoramic image of Coffman Union surroundings

By copying RGB value of original image coordinate (u, v) to the cylindrical coordinate $(, h)$, we create a panoramic image as shown in Fig. 4.

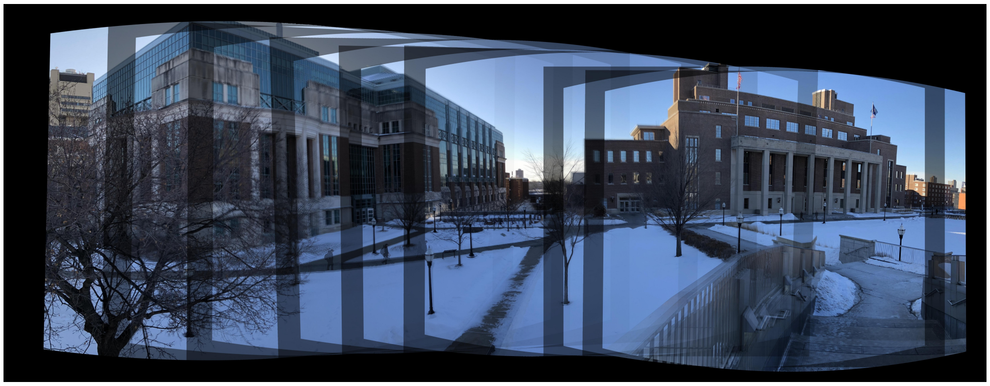


Figure 4: Panoramic image of Coffman Union surroundings