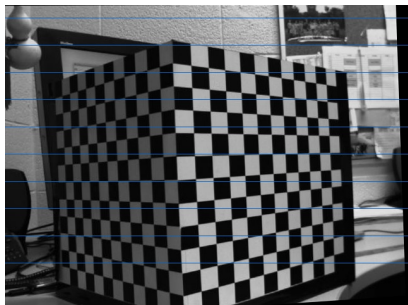
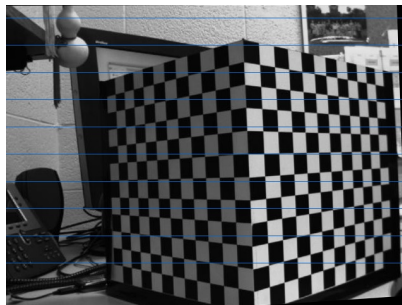


Task 1 - Unknown Intrinsic and Extrinsic Parameters

Without knowing any of the parameters for the image capture device, it is very hard to keep the images aligned or to keep projective form. The images are quite distorted, but corresponding points do match up along horizontal lines. Without any camera parameters, we are only able to reconstruct a scene up to a projective transformation.



(a) Start



(b) End

Figure 1: Parallel Cube

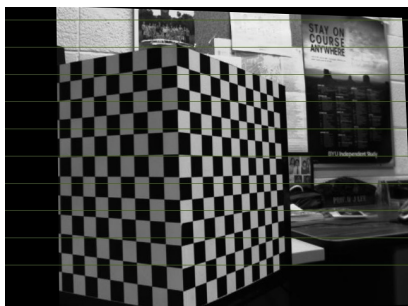


(a) Start

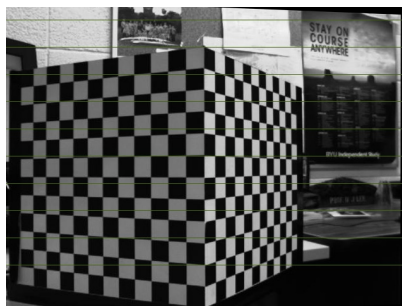


(b) End

Figure 2: Parallel Real



(a) Start

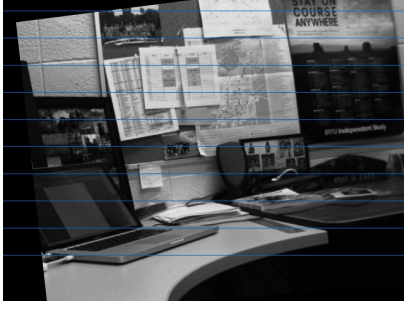


(b) End

Figure 3: Turned Cube

Task 2 - Known Intrinsic Parameters

It is observed that the decomposition of the fundamental matrix creates motion that makes good sense. We can play the sequence of images and see readily that the camera is moving from right to left, essentially entirely in the x-direction. When the fundamental matrix is decomposed correctly, we see this same behavior, up to a scale factor. The math is such that the transformation vector has a norm of 1.



(a) Start



(b) End

Figure 4: Turned Real

The rotation matrices largely appear to be very very close to the identity matrices. The only exception that deviates significantly is in the turned real sequence, which would be understandable that the camera turns somewhat.

The following are the R, T, E, and F matrices for each type of transformation:

Parallel Real

F – parallel real:

$$\begin{bmatrix} -4.29676e-07 & 0.000150455 & -0.0132263 \\ -0.000137004 & -7.04904e-06 & -0.424941 \\ 0.0109562 & 0.417858 & 1 \end{bmatrix}$$

E – parallel real:

$$\begin{bmatrix} -0.0011441 & 0.256827 & 0.0494144 \\ -0.232793 & -0.00627945 & -0.971162 \\ -0.0506966 & 0.965185 & -0.00758867 \end{bmatrix}$$

R – parallel real:

$$\begin{bmatrix} -0.9997 & 0.000256749 & -0.0244807 \\ -0.000417606 & -0.999978 & 0.00656588 \\ 0.0244785 & -0.00657414 & -0.999679 \end{bmatrix}$$

T – parallel real:

$$\begin{bmatrix} 0.965193 & 0.051115 & -0.256497 \end{bmatrix}$$

Parallel Cube

F – parallel cube:

$$\begin{bmatrix} 2.16243e-07 & 1.50848e-05 & -0.00938923 \\ -4.44753e-06 & 4.22347e-06 & -0.318471 \\ 0.00728704 & 0.313221 & 1 \end{bmatrix}$$

E – parallel cube:

$$\begin{bmatrix} 0.000559038 & 0.0388508 & -0.0170599 \\ -0.0116103 & 0.00553807 & -0.999768 \\ 0.0195876 & 0.999039 & 0.00597645 \end{bmatrix}$$

R – parallel cube:

$$\begin{bmatrix} -0.999628 & 0.00246471 & -0.027144 \\ -0.0023159 & -0.999982 & -0.00551236 \\ 0.0271571 & 0.00544745 & -0.999616 \end{bmatrix}$$

T – parallel cube:

$$\begin{bmatrix} 0.999099 & -0.0172802 & -0.0387574 \end{bmatrix}$$

Turned Real

F – turned real:

$$\begin{bmatrix} -5.64669e-07 & 4.34349e-05 & -0.0220842 \\ -3.6285e-05 & 2.06365e-06 & 0.138153 \\ 0.0202722 & -0.141181 & 1 \end{bmatrix}$$

E – turned real:

$$\begin{bmatrix} -0.00321248 & 0.272316 & -0.087248 \\ -0.228974 & 0.00998507 & 0.969691 \\ 0.0822613 & -0.958434 & 0.00543935 \end{bmatrix}$$

R – turned real:

$$\begin{bmatrix} -0.85993 & -0.164906 & -0.483038 \\ -0.161844 & 0.98563 & -0.0483654 \\ -0.484073 & -0.0365857 & 0.874263 \end{bmatrix}$$

T – turned real:

$$\begin{bmatrix} 0.958239 & 0.0846855 & 0.273143 \end{bmatrix}$$

Turned Cube

F – turned cube:

$$\begin{bmatrix} 1.69916e-08 & 8.73677e-06 & -0.00253715 \\ -4.82891e-06 & 5.61749e-06 & -0.0834156 \\ 0.00154827 & 0.0778403 & 1 \end{bmatrix}$$

E – turned cube:

$$\begin{bmatrix} 0.000290298 & 0.0872629 & -0.00138408 \\ -0.0477024 & 0.0274256 & -0.998478 \\ 0.00538237 & 0.995799 & 0.0274246 \end{bmatrix}$$

R – turned cube:

$$\begin{bmatrix} 0.990856 & -0.00543455 & -0.134813 \\ -0.00915855 & -0.999593 & -0.0270186 \\ -0.134611 & 0.0280063 & -0.990503 \end{bmatrix}$$

T – turned cube:

$$\begin{bmatrix} 0.996184 & -0.00377576 & -0.0871926 \end{bmatrix}$$

Task 3 - Known Extrinsic and Intrinsic Parameters

In order to find the scale factor, I made code where I could select a ROI around the leading edge of each cube by using a mouse event handler. I then found the Z values for all of these points (using their corresponding points I had loaded in from the last task), and found the closest z-value. I then found the scale factor by dividing 20 by this Z factor, which then means that all of the points in an image can be scaled by that factor. I scaled the translations in each image by this scale factor, with this result (all measurements are in inches):

Turned Cube T

$$\begin{bmatrix} 9.22723 & -0.03497 & -0.80762 \end{bmatrix}$$

Parallel Cube T

$$\begin{bmatrix} 13.1852 & -0.2280 & -0.51148 \end{bmatrix}$$

Turned Real T

$$\begin{bmatrix} 8.8757 & 0.784405 & 2.5300 \end{bmatrix}$$

Parallel Real T

$$\begin{bmatrix} 12.7377 & 0.67457 & -3.3850 \end{bmatrix}$$

I also chose random points in the image, found their 3D information, and drew them on the image. For convenience, I also wrote the number corresponding to each point on the image by the point. Some of the points may not correlate very well because, due to the random points, some may not have been tracked as precisely.

Parallel Cube

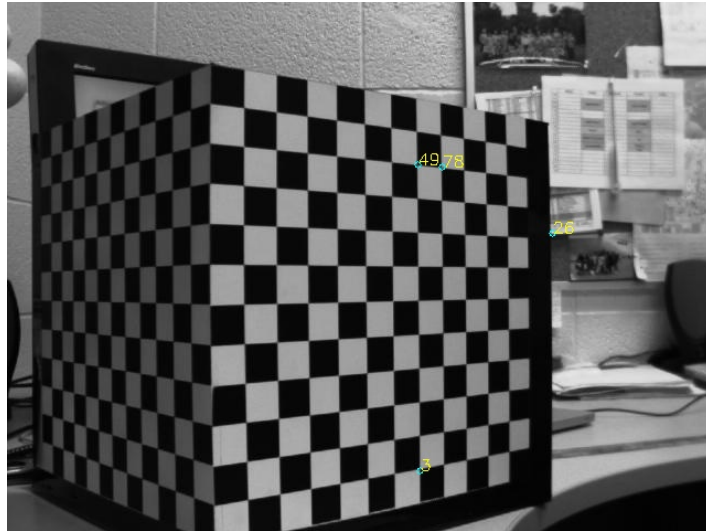


Figure 5: Parallel Cube

Real-world xyz coordinates for point 3 are 11.2461, 12.7511, 24.7864
 Real-world xyz coordinates for point 26 are 11.9565, 5.0493, 19.9743
 Real-world xyz coordinates for point 49 are 11.2366, 4.43982, 24.9452
 Real-world xyz coordinates for point 78 are 11.3703, 4.30705, 23.8204

Turned Cube

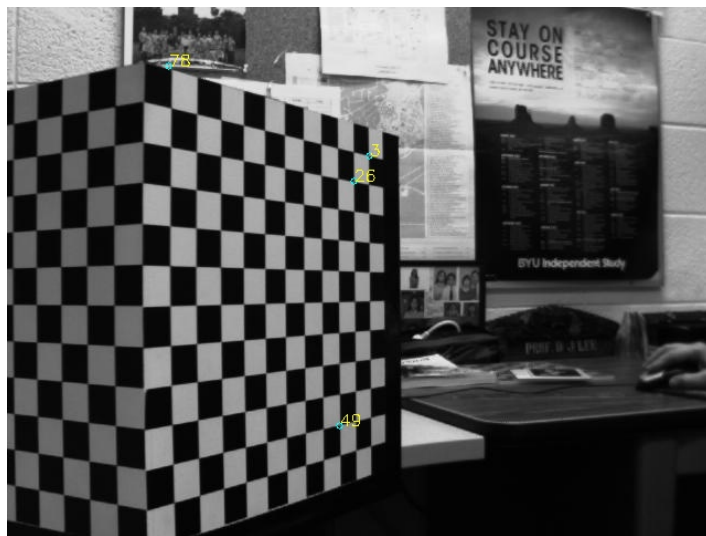


Figure 6: Turned Cube

Real-world xyz coordinates for point 3 are 7.67408, 3.13125, 19.3248
 Real-world xyz coordinates for point 26 are 7.59514, 3.80491, 19.9467
 Real-world xyz coordinates for point 49 are 7.59404, 9.52815, 20.7812
 Real-world xyz coordinates for point 78 are 6.17592, 2.25641, 34.9383

Parallel Real



Figure 7: Parallel Real

Real-world xyz coordinates for point 3 are 11.3698, 20.5212, 42.4328
 Real-world xyz coordinates for point 26 are 14.2449, 5.36123, 21.6319
 Real-world xyz coordinates for point 49 are 11.8756, 7.21613, 42.1685
 Real-world xyz coordinates for point 78 are 14.3983, 5.73535, 20.696
Turned Real

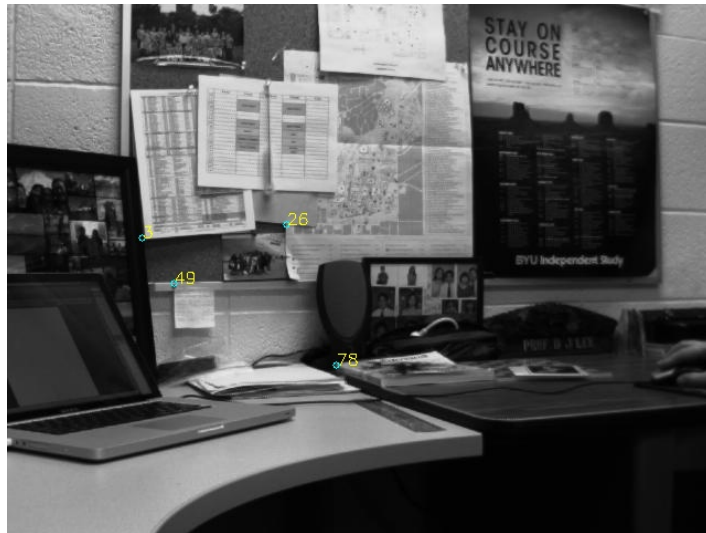


Figure 8: Turned Real

Real-world xyz coordinates for point 3 are 6.94562, 11.9894, 46.8938
 Real-world xyz coordinates for point 26 are 9.25938, 7.29853, 30.2007
 Real-world xyz coordinates for point 49 are 7.29249, 12.2138, 39.9596
 Real-world xyz coordinates for point 78 are 9.00928, 9.8619, 24.9461