ENPM 673 Project 3

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The concept of stereo vision will be implemented in this project. We'll be given three data sets, each of which comprises two photographs of the same scenario shot from two distinct camera perspectives. We can gather 3D information by comparing information about a scene from two vantage points and assessing the relative locations of objects. We also estimate the camera pose with respect to the world.

Calibration:

Since we use SIFT which for the detection of the matching points we initially process the image before we feed into SIFT and then get the matching done by using the *cv*2.BFMatcher as that here can give us a better output than FLANN matcher even if it takes longer and the accuracy is maintained.

Fundamental Matrix:

- A point in the image can be anywhere along the ray drawn from that point to the world. We also know that lines correspond to lines in the perspective projection so a line containing a center of projection and point P in the left image will project a line onto the right image.
- Now, any point in the world along that ray will be on the line (epipolar line) of right image. The epipolar line

is made up by the plane containing image centers and point p in the world and image plane intersection. The converse is also true and so any point on the epipolar line of right image will be on the epipolar line of left image. This is the epipolar constraint.

- This constraint helps in reducing the correspondence problem to a one dimensionel search meaning, we are looking for matching points, and above correspondence points some are not accurate. so, we can search for that points on the epipolar line. if our cameres are parallel our lines will be horizontal and we can search along that line. if our cameras are converged, we rectify it, meaning make our cameras parallel, to get parallel epipolar lines and then search for the match.
- From the camera intrinsic matrix the A matrix is obtained for this system with 9 unknowns and each returns one equation which is a scalar when a constraint for one of the equation is added and this can be obtained using the 8 point hartley algorithm and the resulting matrix will be:

$$Af = \begin{bmatrix} x'_1x_1 & x'_1y_1 & x'_1 & y'_1x_1 & y'_1y_1 & y'_1 & x_1 & y_1 & 1 \\ x'_1x_1 & x'_1y_1 & x'_1 & y'_1x_1 & y'_1y_1 & y'_1 & x_1 & y_1 & 1 \end{bmatrix} f = 0$$

- Now we know that the x_1 and $x'1$ are the features In which the $X^T .F.X_1 = 0$ is the constraint that allows us to solve using the SVD and this causes multiple errors in case the rank is higher than 2, which due to normalization needs to be redone using the epipolar constraint and best fit selected using the RANSAC.

RANSAC:

We use RANSAC to reject the outliers after normalization to get the best fit as it should not have a null value and to get the inliers of the epipolar lines and the threshold must be chosen in such a way that we are able to reduce all the erroneous values to decrease the processing requirement as well.

Essential Matrix

This is taken from the equation $E = K'^{T} .F.K$ from the intrinsic parameters that are known and then using which we obtain the pose information.

Camera Pose:

- From the essential matrix we obtain the pose of the cameras with respect to each other.
- Where Rotation and translation are obtained as 4 possible mathematical solution after decomposing E using SVD as $E = UDV^T$. This is namely R_1 and R_2 which will be $R_1 = UWV^T$ and $R_2 = uWTV^T$ and as we know the matrix:

$$W = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

- If we take the third column of U to be t then the poses can be taken as (R_1,t),(R_1,-t),(R_2,t) and (R_2,-t) of first camera with respect to the second camera.
- In the chance that all the elements of t are zero then of the above possibilities only one is valid as the points need to be positive and the maximum positive value is considered.

Rectification:

- The fundamental matrix we estimated earlier we an obtain the lines needed to make the images parallel.

- This process is using the epipolar constraint for the transformation. The H1 and the H2 homography matrices are calculated using the function and the rectification is obtained.
- The computed H1 and H2 are used to project the images to the desired position with the help of warp perspective.

Correspondence:

The left and the right images are taken and the points between them are matched to find the corresponding epipolar lines. A generalized block matching would yield acceptable results when implemented through Sum of Squared Differences and the disparity is calculated by using the image pixel difference with respect to the width of the image. Here the depth map is computed by using the formula of

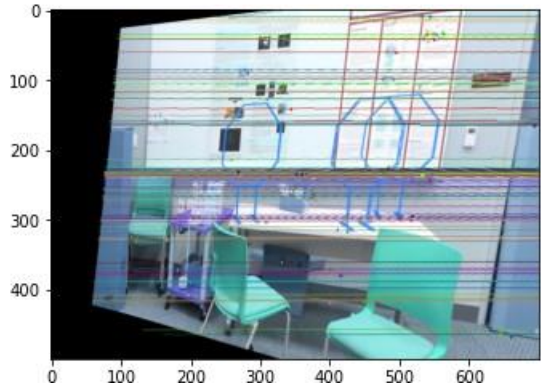
$$z = \frac{baseline \times f}{disparity}$$

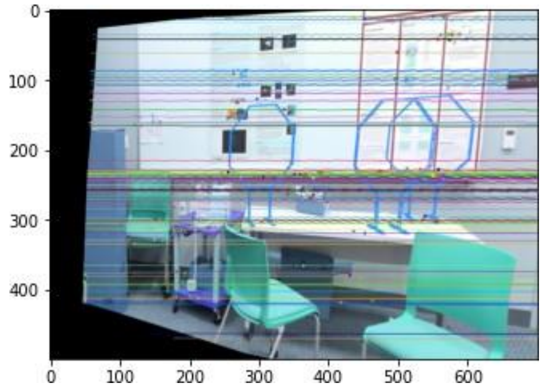
Output

Output containing the Fundamental matrix, Essential Matrix, Rotation and Translation Matrices and the Homography matrices and the epilopar lines for the three datasets.

Dataset 1:

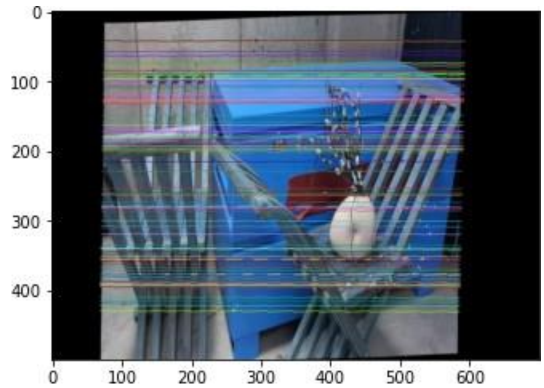
```
F matrix
 [[ 2.64146637e-07  1.13262877e-03 -1.94122561e-01]
 [-1.12851289e-03 -7.02216335e-07  2.16253909e+00]
 [ 1.91482943e-01 -2.15224092e+00  1.00000000e+00]]
E Matrix
 [[ 2.55280314e-04  8.33228372e-01  1.76935182e-01]
 [-8.29749262e-01 -5.39954429e-04  5.29170355e-01]
 [-1.76910703e-01 -5.24041424e-01  1.46672438e-03]]
Rotation
 [[-0.44536623 -0.18584889  0.87584765]
 [-0.18683176 -0.93739504 -0.29391229]
 [ 0.87563852 -0.29453477  0.38276161]]
Translation
 [[-0.52385528]
 [ 0.1774672 ]
 [-0.83311526]]
Homography Mat 1 :  [[ 1.49182419e+00 -2.02234799e-01  2.50772188e+02]
 [-2.31185899e-01  2.17274326e+00  7.06233748e+01]
 [-1.36496954e-03  5.43104758e-05  2.59538931e+00]]
Homography Mat 2 :  [[ 7.96928706e-01 -3.52382150e-02  7.34399857e+01]
 [-1.07396986e-01  1.00572595e+00  3.29928085e+01]
 [-6.31547283e-04  2.79254578e-05  1.19539302e+00]]
```

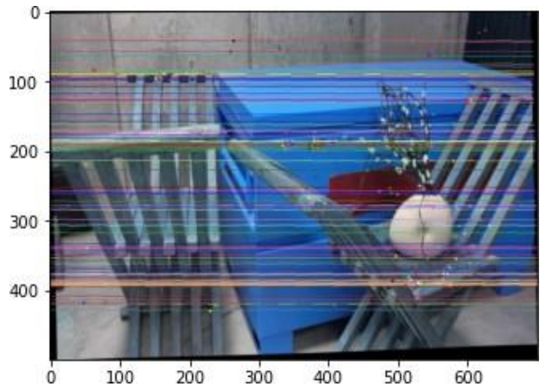




Dataset 2:

```
F matrix
 [[-2.15458850e-07  3.79266848e-05  2.86158725e-02]
 [-2.53031717e-05 -2.05699949e-05 -2.19548152e+00]
 [-3.19065136e-02  2.20444005e+00  1.00000000e+00]]
E Matrix
 [[-1.71160547e-04  2.96903424e-02  2.18481362e-02]
 [-2.01045933e-02 -7.59405649e-03 -9.99525307e-01]
 [-2.08263116e-02  9.99316484e-01 -7.82558379e-03]]
Rotation
 [[ 0.00946253 -0.70059632 -0.7134951 ]
 [-0.03656601  0.71280739 -0.70040599]
 [ 0.99928644  0.03271729 -0.01887305]]
Translation
 [[ 0.99932033]
 [ 0.0220748 ]
 [-0.0295227 ]]
Homography Mat 1 :  [[ 1.63181224e+00 -3.35902143e-02  1.64490507e+02]
 [-3.32765643e-02  2.20306859e+00  1.01400833e+01]
 [ 1.97643948e-05  1.57039340e-05  2.18357379e+00]]
Homography Mat 2 :  [[ 1.00529027e+00  1.71231515e-02 -5.80244362e+00]
 [-1.29540941e-02  9.99924404e-01  4.16345314e+00]
 [ 1.69853232e-05  2.89311723e-07  9.94495262e-01]]
```





Dataset 3:

```
F matrix
 [[ 4.67174786e-07 -3.72820997e-04  1.00167622e-01]
 [ 3.60147116e-04 -1.45849920e-05  1.05664671e+00]
 [-9.53223711e-02 -1.05522160e+00  1.00000000e+00]]
E Matrix
 [[-0.00319091 -0.56896263 -0.09923144]
 [ 0.55833497 -0.01263439  0.82422563]
 [ 0.08709148 -0.81703582 -0.00682217]]
Rotation
 [[ 0.99986907 -0.00805517  0.01403384]
 [ 0.0079157   0.99991901  0.00996542]
 [-0.01411298 -0.00985303  0.99985186]]
Translation
 [[ 0.81634825]
 [ 0.0935657 ]
 [-0.56993069]]
Homography Mat 1 :  [[-1.03310273e+00  8.42143410e-02  2.02927366e+00]
 [-8.94338143e-02 -1.06306411e+00  2.96491770e+01]
 [-3.33972784e-04  7.31537569e-06 -9.54638398e-01]]
Homography Mat 2 :  [[ 1.10118958e+00 -9.88056872e-03 -3.00093284e+01]
 [ 8.48946429e-02  9.99278525e-01 -2.69931317e+01]
 [ 3.16343217e-04 -2.83843124e-06  8.99451394e-01]]
```