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Steps:

- 1. Find the Sift features.
- 2. Matches before RANSAC
- 3. Matches using RANSAC
- 4. Essential Matrix.
- 5. Rotation and Translation Matrix
- 6. Projection Matrix and Triangulation.
- 7. plot 3D points.

```
In [3]: # import neccessary libraries
import cv2
import numpy as np
from mpl_toolkits.mplot3d import Axes3D
import matplotlib.pyplot as plt
```

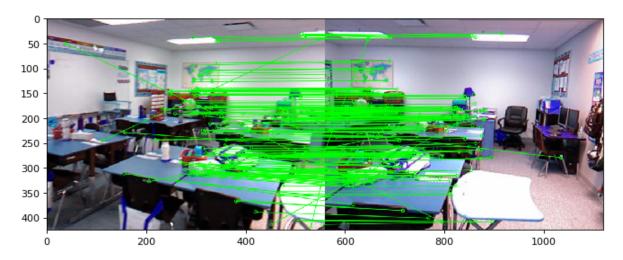
```
In [58]: # SFM() fucntion takes two images as Input
         # shows the matches, Essential matrix, Rotation and translation matrix and 3d-
         points.
         def SFM(image1,image2):
             MIN MATCH COUNT = 10
             #TODO: Load Different Image Pairs
             img1=cv2.imread(image1)
             img2=cv2.imread(image2)
             #TODO: Replace K with given Intrinsic Matrix
             K = np.array([[518.86, 0., 285.58],
                           [0., 519.47, 213.74],
                           [0., 0., 1.]
             #1----SIFT feature matching---#
             #detect sift features for both images
             sift = cv2.xfeatures2d.SIFT_create()
             kp1, des1 = sift.detectAndCompute(img1,None)
             kp2, des2 = sift.detectAndCompute(img2,None)
             #use flann to perform feature matching
             FLANN INDEX KDTREE = 0
             index_params = dict(algorithm = FLANN_INDEX_KDTREE, trees = 5)
             search params = dict(checks = 50)
             flann = cv2.FlannBasedMatcher(index params, search params)
             matches = flann.knnMatch(des1,des2,k=2)
             # store all the good matches as per Lowe's ratio test.
             good = []
             for m,n in matches:
                 if m.distance < 0.7*n.distance:</pre>
                     good.append(m)
             if len(good)>MIN_MATCH_COUNT:
                 p1 = np.float32([ kp1[m.queryIdx].pt for m in good ]).reshape(-1,1,2)
                 p2 = np.float32([ kp2[m.trainIdx].pt for m in good ]).reshape(-1,1,2)
             draw params = dict(matchColor = (0,255,0), # draw matches in green color
                               singlePointColor = None,
                               flags = 2)
             img siftmatch = cv2.drawMatches(img1,kp1,img2,kp2,good,None,**draw params)
             ###### Display matchings before Ransac
             print("Before RANSAC:")
             plt.figure(num=None, figsize=(10, 10), dpi=80, facecolor='w', edgecolor=
         'k')
             plt.imshow(img siftmatch)
```

```
plt.show()
    #####################################
    #2---essential matrix--#
    ###################################
    E, mask = cv2.findEssentialMat(p1, p2, K, cv2.RANSAC, 0.999, 1.0);
    matchesMask = mask.ravel().tolist()
    draw params = dict(matchColor = (0,255,0), # draw matches in green color
                        singlePointColor = None,
                        matchesMask = matchesMask, # draw only inliers
                        flags = 2)
    img_inliermatch = cv2.drawMatches(img1,kp1,img2,kp2,good,None,**draw_param
s)
    ###### Display matchings After Ransac
    print("After RANSAC:")
    plt.figure(num=None, figsize=(10, 10), dpi=80, facecolor='w', edgecolor=
'k')
    plt.imshow(img inliermatch)
    plt.show()
    print ("Essential matrix:")
    print (E)
    ####################
    #3----recoverpose--#
    ######################
    points, R, t, mask = cv2.recoverPose(E, p1, p2)
    print ("Rotation:")
    print (R)
    print ("Translation:")
    print (t)
    # p1_tmp = np.expand_dims(np.squeeze(p1), 0)
    p1_tmp = np.ones([3, p1.shape[0]])
    p1_{tmp}[:2,:] = np.squeeze(p1).T
    p2\_tmp = np.ones([3, p2.shape[0]])
    p2\_tmp[:2,:] = np.squeeze(p2).T
    print ((np.dot(R, p2 tmp) + t) - p1 tmp)
    ############################
    #4----triangulation---#
    #############################
    #calculate projection matrix for both camera
    M r = np.hstack((R, t))
    M_1 = \text{np.hstack}((\text{np.eye}(3, 3), \text{np.zeros}((3, 1))))
    P l = np.dot(K, M l)
    P_r = np.dot(K, M_r)
    # undistort points
    p1 = p1[np.asarray(matchesMask)==1,:,:]
    p2 = p2[np.asarray(matchesMask)==1,:,:]
    p1 un = cv2.undistortPoints(p1, K, None)
```

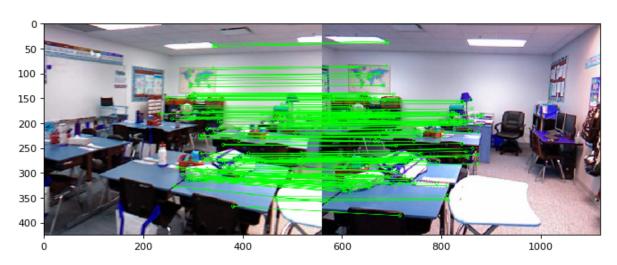
```
p2 un = cv2.undistortPoints(p2, K, None)
   p1_un = np.squeeze(p1_un)
   p2_un = np.squeeze(p2_un)
   #triangulate points this requires points in normalized coordinate
   point_4d_hom = cv2.triangulatePoints(M_l, M_r, p1_un.T, p2_un.T)
   point_3d = point_4d_hom / np.tile(point_4d_hom[-1, :], (4, 1))
   point_3d = point_3d[:3, :].T
   #5----output 3D pointcloud--#
   #####################################
   #TODO: Display 3D points
   print("3-D points")
   print("-----"Multiple Views-----"
)
   fig = plt.figure(num=None, figsize=(14, 9), dpi=80, facecolor='w', edgecol
or='k')
   ax1 = fig.add_subplot(2, 2, 1, projection='3d')
   ax1.scatter(point_3d[:,0], point_3d[:,1], point_3d[:,2])
   ax1.view init()
   ax2 = fig.add subplot(2, 2, 2, projection='3d')
   ax2.scatter(point_3d[:,0], point_3d[:,1], point_3d[:,2])
   ax2.view_init(20,20)
   ax3 = fig.add_subplot(2, 2, 3, projection='3d')
   ax3.scatter(point_3d[:,0], point_3d[:,1], point_3d[:,2])
   ax3.view_init(20,40)
   ax4 = fig.add subplot(2, 2, 4, projection='3d')
   ax4.scatter(point_3d[:,0], point_3d[:,1], point_3d[:,2])
   ax4.view_init(20,60)
   plt.show()
     fig = plt.figure()
#
     ax = Axes3D(fig)
#
     ax.autoscale(enable=True,axis='both',tight=None)
     ax.scatter(point_3d[:,0], point_3d[:,1], point_3d[:,2])
#
# #
       ax.view_init(20,60)
#
     plt.show()
```

In [59]: SFM('HW4_data/a1.png','HW4_data/a2.png')

Before RANSAC:



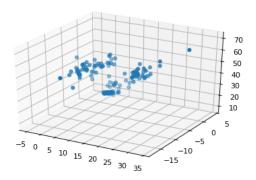
After RANSAC:

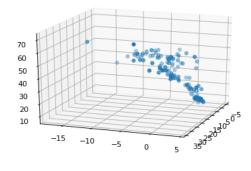


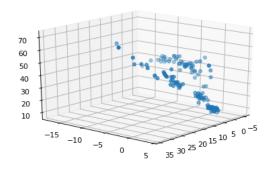
```
Essential matrix:
[[ 0.03528635 -0.64288702  0.00591349]
[ 0.49341659  0.02860999  -0.50550657]
 [-0.0264357 0.29126999 0.00798598]]
Rotation:
[[ 0.93091564  0.04776478  -0.3620975 ]
 [-0.04716958 0.99883182 0.01048912]
 [ 0.36217552  0.0073155  0.93208121]]
Translation:
[[-0.41331871]
[-0.01921728]
 [-0.91038362]]
[[ 2.01093932e+02 -1.00079762e+02 -8.64155536e+01 7.58626155e+01
   1.02391160e+02 8.60376854e+01 -2.17275593e+02 -2.19148232e+02
 -2.19497506e+02 -2.20954578e+02 -2.16717648e+02 -2.19676020e+02
  -2.39285400e+02 -2.39285400e+02 -2.31986772e+02 -2.14733153e+02
 -2.31372076e+02 -2.30190552e+02 -2.12960135e+02 -2.29142655e+02
 -2.30760233e+02 -2.10340313e+02 -2.28887388e+02 -2.14436623e+02
  -2.14191896e+02 -2.28607618e+02 -2.29520346e+02 -2.18574369e+02
 -2.30209497e+02 -2.12923531e+02 -2.16655371e+02 3.70077667e+01
  -2.15273890e+02 -2.28015057e+02 -2.08082235e+02 -2.15096528e+02
 -2.12147634e+02 -2.27875776e+02 -2.13017857e+02 -2.11478218e+02
 -2.12049743e+02 -2.12049743e+02 -2.11325631e+02 -2.10403697e+02
  -2.28982839e+02 -2.27219050e+02 -2.09231242e+02 -2.12360370e+02
  -2.15080955e+02 -2.15570924e+02 -2.24099734e+02 -2.04625539e+02
  -2.03145805e+02 -2.03145805e+02 -2.26844565e+02 -2.10134251e+02
   1.37270575e+02 -2.24873766e+02 -2.02864499e+02 -2.07734701e+02
  -2.15345623e+02 -2.22845029e+02 -2.22383272e+02 -2.21687140e+02
  -2.22264896e+02 -2.24116354e+02 -2.15003328e+02 -2.22179591e+02
  -2.21887083e+02 -2.23660535e+02 -2.20225862e+02 -2.03341328e+02
  -2.07132428e+02 -2.07963590e+02 -2.12058952e+02 -2.10781577e+02
 -2.19802817e+02 -2.21197757e+02 -2.15960768e+02 -2.07554911e+02
  -2.07554911e+02 -2.18505599e+02 -2.18505599e+02 -2.07294432e+02
  -2.22110233e+02 -2.19095672e+02 -2.11784129e+02 -2.06158169e+02
 -2.09599866e+02 -2.05343969e+02 -2.05919514e+02 -2.20531131e+02
  -2.04746899e+02 -2.20547242e+02 -2.20547242e+02 -2.17600483e+02
 -2.04236320e+02 -2.10325131e+02 -2.08779577e+02 -2.19083424e+02
  -2.09151556e+02 -2.11586334e+02 -2.09505919e+02 -2.17506139e+02
  -2.19767768e+02 -2.11813794e+02 -2.17185827e+02 -2.17473891e+02
  -2.16988748e+02 -2.16988748e+02 -2.15083167e+02 -2.17454009e+02
 -2.16000986e+02 -2.19231472e+02 -2.21849761e+02 -2.16701757e+02
 -2.16195483e+02 -2.15868835e+02 -2.15584646e+02 -2.15584646e+02
  -2.10140532e+02 -2.10749733e+02 -2.17227387e+02 -2.09181722e+02
  -2.15449808e+02 -2.15589181e+02 -2.11312408e+02 -2.18472022e+02
  -2.10176951e+02 -2.14578213e+02 -2.16407098e+02 -2.10822289e+02
 -2.14818788e+02 -2.07743137e+02 -2.16882691e+02 -2.17587664e+02
 -2.13026679e+02 -2.12951557e+02 -2.13045311e+02 -2.21235245e+02
  -2.12687704e+02 -1.94878817e+02 -2.12129303e+02 -2.15253380e+02
  -2.15318057e+02 -2.15149370e+02 -2.16668217e+02 -2.15228760e+02
  -2.15562627e+02 -2.16763736e+02 -2.16763736e+02 -2.16388651e+02
 -2.15056795e+02 -2.16591411e+02 -2.15444121e+02 -2.17609300e+02
 -2.13993526e+02 -2.17770404e+02 -2.17770404e+02 -2.17592806e+02
 -2.17592806e+02 -2.19124347e+02 -2.17971767e+02 -2.17971767e+02
 -2.17093211e+02 -2.17897840e+02 -2.17106509e+02 -2.19174046e+02
  -2.22504542e+02 -2.22504542e+02 -2.19368719e+02 -2.19586905e+02
 -2.21664040e+02 -2.19217542e+02 -2.19417554e+02 -2.17687033e+02
  -2.15494336e+02 -2.13214233e+02 -2.12203699e+02 -2.20585686e+02
```

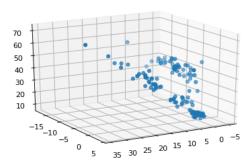
```
-2.25185381e+02 -2.45572949e+02 -2.23410908e+02 -2.37705928e+02
-2.23831713e+02 -2.23165034e+02 -2.15561198e+02 -2.37768049e+02
-2.37768049e+02 -2.19093650e+02 -2.20768161e+02 -2.20768161e+02
-2.25295188e+02 -2.24194073e+02 -5.11613215e+02 -2.26844811e+02
-2.27988363e+02 -2.27080861e+02 -4.58094866e+02 -2.20444109e+02
-4.66283343e+02 -2.22741727e+02]
[ 3.46355160e+02 -2.14085458e+02 5.82802197e+01 3.41873899e+01
-1.41926272e+02 -2.31754337e+01 2.51107083e+00 -1.10748041e+00
-1.30088556e+00 -2.11767176e+00 -4.96733156e+00 2.57720729e+00
 3.13101693e+01 3.13101693e+01 1.96194133e+01 -1.35321987e+00
 1.71049150e+01 1.94703817e+01 -1.47764952e+00 1.98264761e+01
 1.25100305e+01 -9.73943979e-01 1.98269661e+01 -3.50090026e+00
-4.68669659e+00 1.87537091e+01 1.57385465e+01 -9.71057253e+00
 1.46147831e+01 -4.53331542e+00 -8.97560869e+00 -2.43252053e+01
-5.65754718e+00 1.90220265e+01 -1.67915033e+00 -7.32765547e+00
-4.47910826e+00 1.92139447e+01 -5.42783572e+00 -5.48063666e+00
-5.50726290e+00 -5.50726290e+00 -4.43308422e+00 -4.90363031e+00
 1.45208162e+01 1.62145992e+01 -3.18674840e+00 -5.75565507e+00
-7.87217987e+00 -8.32623884e+00 1.41110140e+01 -4.68847583e-02
-9.52830904e-01 -9.52830904e-01 5.36484887e+00 -6.78420544e+00
 6.16230910e+01 1.19321029e+01 -1.45076745e-01 -4.25875034e+00
-9.40993269e+00 5.57981496e+00 1.22598619e+01 1.15280743e+01
 1.10033068e+01 1.05247400e+01 -9.31102347e+00 5.12194153e+00
 1.07433938e+01 1.23502827e+01 7.23969013e+00 -2.87242460e+00
-5.51044166e+00 -5.42715832e+00 -8.15730799e+00 -6.66036749e+00
 2.85575390e+00 2.37741496e+00 -1.08101846e+01 -5.90211082e+00
-5.90211082e+00 -1.28393519e+01 -1.28393519e+01 -4.59591423e+00
-1.27813578e+01 6.40757155e+00 -3.55491132e+00 -6.00969899e+00
-8.67688824e+00 -5.25452507e+00 -6.50006778e+00 3.80568340e+00
-5.61335858e+00 2.96301011e+00 2.96301011e+00 2.41177376e-01
-6.03454681e+00 -5.26704947e+00 -9.50808142e+00 4.93588265e-01
-8.86942480e+00 -4.93562993e+00 -5.60610871e+00 3.34184876e-01
 3.14685971e+00 -6.28947853e+00 4.18756471e+00 8.67141447e-01
-2.85146582e-01 -2.85146582e-01 1.60257316e+00 1.08205754e+01
-8.82050885e-01 -3.60662158e+00 1.25000798e+01 -4.27359511e+00
-4.34153298e+00 -1.27478322e+00 -6.24508063e+00 -6.24508063e+00
-8.89260446e+00 -9.36487079e+00 -6.90624252e+00 -7.49929922e+00
-1.70894031e+00 -2.21034412e+00 -9.75707067e+00 -7.81918144e+00
-1.05374954e+01 -2.16921940e+00 -7.05691492e+00 -1.07373776e+01
-8.84548694e+00 2.04440743e+00 -9.29852378e+00 -1.09286269e+01
-1.15352093e+01 -1.36411138e+01 -1.22281221e+01 -1.03583397e+01
-1.53329213e+01 -2.15022801e+02 -1.44457190e+01 -1.51438159e+01
-1.25637905e+01 -1.30650144e+01 -1.30026034e+01 -1.55734664e+01
-1.37577568e+01 -1.49515076e+01 -1.49515076e+01 -1.49945322e+01
-1.64963272e+01 -1.65194779e+01 -1.29863507e+01 -1.56846456e+01
-1.79790414e+01 -1.46839875e+01 -1.46839875e+01 -1.63542315e+01
-1.63542315e+01 -1.42395153e+01 -1.59868141e+01 -1.59868141e+01
-1.70404424e+01 -1.71179552e+01 -1.93687135e+01 -1.73300978e+01
-1.46235377e+01 -1.46235377e+01 -1.76224164e+01 -1.70949506e+01
-1.57024481e+01 -1.80755275e+01 -1.82658321e+01 -2.04599820e+01
-2.07684738e+01 -2.23724888e+01 -1.14074860e+01 -1.94053962e+01
-1.60219988e+01 -1.67137267e+01 -1.75367208e+01 -1.10456854e+01
-1.88655074e+01 -2.27222230e+01 -1.41175405e+01 -1.02880652e+01
-1.02880652e+01 -2.49906055e+01 -2.50553880e+01 -2.50553880e+01
-1.89083556e+01 -2.10691492e+01 -1.48733653e+02 -2.08480345e+01
-1.95588954e+01 -1.94625897e+01 -2.77357134e+02 -2.73433650e+01
-3.70410714e+00 -2.25267191e+011
```

1.16773374e+02	[8.73624060e+01	3.64868628e+00	2.21792801e+01	8.66514780e+01
8.66033071e+00 8.30020014e+00 1.10488825e+01 1.20345195e+01 4.85523376e+00 1.4506835e+01 1.4506835e+01 1.4506835e+01 1.4506835e+01 1.4506835e+01 1.4506835e+01 1.7583594e+01 1.76568670e+01 1.97720102e+01 1.98886738e+01 2.68849531e+01 2.02633884e+01 2.88880684e+01 2.88880684e+01 2.88880684e+01 2.88880684e+01 2.88880684e+01 2.88880684e+01 2.88880684e+01 2.981256953e+01 1.27917814e+02 2.87201887e+01 2.18621075e+01 3.12442485e+01 2.93843443e+01 3.26590117e+01 3.98454677e+01 3.98454677e+01 3.98454677e+01 3.98454677e+01 3.98454677e+01 3.98454677e+01 3.985969401 4.938099e+01 4.88741583e+01 3.52609548e+01 4.938099e+01 4.98741583e+01 3.52609548e+01 4.938099e+01 4.98741583e+01 3.596096438e+01 4.52590278e+01 4.12627332e+01 3.57257828e+01 3.69696438e+01 4.6598905e+01 4.66919191e+01 4.66919191e+01 4.66919191e+01 4.66919191e+01 4.66919191e+01 4.66919191e+01 5.60128779e+01 5.39541574e+01 5.59978e+01 5.471667e+01 5.59978e+01 5.39541574e+01 5.59978e+01 5.2935797e+01 5.48771667e+01 5.59978e+01 5.2935797e+01 5.48771667e+01 5.59978e+01 5.2235599e+01 5.3854159e+01 5.59978e+01 5.2235599e+01 5.48771667e+01 5.59978e+01 5.84572021e+01 6.82541682e+01 6.94591493e+01 5.2232365e+01 5.48772021e+01 6.82541682e+01 6.94591493e+01 5.2232365e+01 5.84572021e+01 6.9885798e+01 6.97784580e+01 5.84572021e+01 6.94591493e+01 7.73561738e+01 6.94591493e+01 7.8608369e+01 8.5909379e+01 9.59756873e+01 9.5975964e+01 9.5975964e+01 9.597596540e+01 6.94591493e+01 7.8761334e+01 9.73613312e+01 9.7365699e+02 1.006967003e+02 1.00766939e+02 1.00776939e+02 1.02773699e+02 1.02773699e+02 1.02773699e+02 1.02773699e+02 1.02773699e	•			
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4.88665771e+01 4.66919191e+01 4.66919191e+01 4.99998064e+01 4.65898095e+01 4.47192163e+01 4.99599510e+01 5.27047276e+01 5.22935797e+01 5.40700165e+01 5.41167581e+01 4.77869814e+01 5.60128779e+01 4.89803051e+01 5.99163999e+01 5.05052093e+01 5.66439159e+01 5.39541574e+01 5.59163999e+01 5.59163999e+01 5.594676e+01 5.594676e+01 5.59163999e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 5.66826175e+01 5.66826175e+01 5.78234623e+01 5.33019062e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.20353867e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.94591493e+01 6.70750108e+01 7.18702992e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.24403297e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.57565873e+01 9.57565873e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.57565873e+01 9.65218417e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034867e+02 1.027765939e+02 1.027765939e+02 1.08808186e+02 1.04788987e+02 1.05690817e+02 1.08808186e+02 1.04788987e+02 1.05667003e+02 1.0776132e+02 1.07765939e+02 1.08808186e+02 1.0478693e+02 1.0478699e+02 1.04786	4.51492617e+01	4.52592727e+01	4.46535949e+01	4.58091185e+01
4.65898095e+01 4.47192163e+01 4.99599510e+01 5.27047276e+01 5.22935797e+01 5.40700165e+01 5.41167581e+01 4.77869814e+01 5.60128779e+01 4.89803051e+01 5.66439159e+01 5.39541574e+01 5.59163999e+01 5.48771667e+01 5.59974800e+01 5.23220365e+01 5.59163999e+01 5.48771667e+01 5.59974800e+01 5.2320365e+01 5.5203782e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.66416796e+01 6.66416796e+01 6.66416796e+01 6.66416796e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.38538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.24403297e+01 9.59565873e+01 9.57565873e+01 9.57565873e+01 9.575965873e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.65218417e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.029388505e+02 1.04788987e+02 1.0958735e+02 1.0958735e+02 1.0958735e+02 1.0958735e+02 1.0958735e+02 1.0958735e+02 1.0958735e+02 1.0958735e+02 1.00602431e+02 1.09527135e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14278209e+02 1.12265699e+02 1.15576422e+02 1.123895581e+02]]	4.14352624e+01	4.14477146e+01	4.64298988e+01	4.88665771e+01
5.22935797e+01 5.40700165e+01 5.41167581e+01 4.77869814e+01 5.60128779e+01 4.89803051e+01 5.05052093e+01 5.66439159e+01 5.39541574e+01 5.59163999e+01 5.05052093e+01 5.59163999e+01 5.48771667e+01 5.59163999e+01 5.2320365e+01 5.15203782e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.29385798e+01 6.37784580e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.66416796e+01 6.99925400e+01 6.97393148e+01 7.32047358e+01 7.39538481e+01 7.3561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.36265364e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.57565873e+01 9.5890379e+01 9.75930935e+01 9.57565873e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.73813213e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02934844e+02 1.02034844e+02 1.09527135e+02 1.05829782e+02 1.06967003e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.16266420e+02 1.0000348903 1.22365598e+02 1.0000348903 1.22365699e+02 1.02365699e+02 1.0000348903 1.22365699e+02 1.02365699e+02 1.0000348903 1.22365699e+02 1.0000348903 1.22365699e+02 1.0000348903 1.22365699e+02 1.0000348903 1.223656	4.88665771e+01	4.66919191e+01	4.66919191e+01	4.90998064e+01
5.60128779e+01 4.89803051e+01 5.05052093e+01 5.66439159e+01 5.39541574e+01 5.59163999e+01 5.05052093e+01 5.59163999e+01 5.48771667e+01 5.59974800e+01 5.22320365e+01 5.15203782e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.66416796e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.38538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.29422477e+01 9.26837977e+01 9.36265364e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.757565873e+01 9.757565873e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.73813213e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02934844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02602431e+02 1.05699817e+02 1.05829782e+02 1.08808186e+02 1.14142602e+02 1.025365699e+02 1.0266420e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.02365699e+02 1.14278209e+02 1.14278209e+02 1.16052482e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 3.23895581e+02]]	4.65898095e+01	4.47192163e+01	4.99599510e+01	5.27047276e+01
5.66439159e+01 5.39541574e+01 5.59163999e+01 5.05052093e+01 5.59163999e+01 5.48771667e+01 5.59974800e+01 5.22320365e+01 5.15203782e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 5.66826175e+01 5.66826175e+01 5.78234623e+01 5.84572021e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94591334e+01 6.66416796e+01 6.66416796e+01 6.94591493e+01 6.70750108e+01 7.18702992e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.24403297e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.57565873e+01 9.6982148e+01 9.73813213e+01 9.88970697e+01 9.87148658e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.02768204e+02 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02934844e+02 1.02034844e+02 1.02034844094000e+02 1.020348440900e+02 1.02034844e+02 1.02034844090e+02 1.02034844090e+02 1.02034844e+02 1.02034844090e+02 1.02034844090e+02 1.0203484000e+02 1.0203484000e+02 1.0203484000e+02 1.0203484000e+02 1.0203484000e+02 1.0203484000e+02 1.0203484000e+02 1.0203484000e+02 1.020348000e+02 1.020348000e+02 1.020348000e+02 1.020348000e+02 1.02034800	5.22935797e+01	5.40700165e+01	5.41167581e+01	4.77869814e+01
5.59163999e+01 5.48771667e+01 5.59974800e+01 5.22320365e+01 5.15203782e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.84572021e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.99925400e+01 6.97393148e+01 7.32047358e+01 7.37561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.24403297e+01 9.69082148e+01 9.13835771e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.73813213e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02934844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08808186e+02 1.04788987e+02 1.05699817e+02 1.08808186e+02 1.048808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.02666420e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.122365699e+02 3.07776093e+01 1.22365699e+02 3.07	5.60128779e+01	4.89803051e+01	4.89803051e+01	5.05052093e+01
5.15203782e+01 5.53404654e+01 5.28188258e+01 5.33019062e+01 5.66826175e+01 5.66826175e+01 5.66826175e+01 5.84572021e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.46930000e+01 8.95090379e+01 9.29422477e+01 9.26837977e+01 9.36265364e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.75930935e+01 9.75930935e+01 9.75930935e+01 9.75930935e+01 9.75930935e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02934844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.027765939e+02 1.08044013e+02 1.0848871e+02 1.06967003e+02 1.07776132e+02 1.05699817e+02 1.08044013e+02 1.08808186e+02 1.04788987e+02 1.05699817e+02 1.08808186e+02 1.0478693e+01 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]	5.66439159e+01	5.39541574e+01	5.59163999e+01	5.05052093e+01
5.66826175e+01 5.66826175e+01 5.78234623e+01 5.84572021e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.20353867e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.387338481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.57565873e+01 9.3813213e+01 9.88970697e+01 9.87148658e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02713002e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.04278209e+02 1.016266420e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]	5.59163999e+01	5.48771667e+01	5.59974800e+01	5.22320365e+01
5.66826175e+01 5.66826175e+01 5.78234623e+01 5.84572021e+01 6.08119943e+01 6.00105613e+01 5.84572021e+01 6.20353867e+01 6.29885798e+01 6.37784580e+01 6.47768115e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.387338481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.57565873e+01 9.3813213e+01 9.88970697e+01 9.87148658e+01 9.78812119e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02713002e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.04278209e+02 1.016266420e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]	5.15203782e+01	5.53404654e+01	5.28188258e+01	5.33019062e+01
6.29885798e+01 6.37784580e+01 6.47768115e+01 6.47768115e+01 6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.94591493e+01 6.70750108e+01 7.18702992e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50084224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.88970697e+01 9.8813213e+01 9.73813213e+01 9.88970697e+01 9.88148658e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02934844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.08448471e+02 1.00602431e+02 1.07765939e+02 1.08044013e+02 1.08988505e+02 1.10761195e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]	5.66826175e+01	5.66826175e+01	5.78234623e+01	5.84572021e+01
6.77036002e+01 6.82541682e+01 6.52554262e+01 6.94153334e+01 6.66416796e+01 6.66416796e+01 6.94591493e+01 6.70750108e+01 7.18702992e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.57565873e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.88970697e+01 9.87148658e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.020348844e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.08808186e+02 1.17353337e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]	6.08119943e+01	6.00105613e+01	5.84572021e+01	6.20353867e+01
6.66416796e+01 6.66416796e+01 6.94591493e+01 6.70750108e+01 7.18702992e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.08908186e+02 1.14340482e+02 1.14278209e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]	6.29885798e+01	6.37784580e+01	6.47768115e+01	6.47768115e+01
7.18702992e+01 6.90925400e+01 6.97393148e+01 7.32047358e+01 7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.08044013e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14376422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]	6.77036002e+01	6.82541682e+01	6.52554262e+01	6.94153334e+01
7.30538481e+01 7.73561738e+01 7.56608846e+01 7.87014085e+01 8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.089041e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]	6.66416796e+01	6.66416796e+01	6.94591493e+01	6.70750108e+01
8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]	7.18702992e+01	6.90925400e+01	6.97393148e+01	7.32047358e+01
8.50070444e+01 8.46930000e+01 8.50884224e+01 8.48178036e+01 8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.08908186e+02 1.08808186e+02 1.14340482e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]	7.30538481e+01	7.73561738e+01	7.56608846e+01	7.87014085e+01
8.95090379e+01 9.69082148e+01 9.13835771e+01 9.36265364e+01 9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.02034844e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.08808186e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]				
9.24403297e+01 9.29422477e+01 9.26837977e+01 9.50509262e+01 9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.077765939e+02 1.08044013e+02 1.09988505e+02 1.10761195e+02 1.09527135e+02 1.05920001e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.1576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]				9.36265364e+01
9.36779305e+01 9.57565873e+01 9.57565873e+01 9.63130594e+01 9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.098448471e+02 1.00602431e+02 1.09527135e+02 1.05920001e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.1576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]				
9.69082148e+01 9.75930935e+01 9.65218417e+01 9.78812119e+01 9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.05920001e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.1576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 3.07776093e+01 1.23895581e+02]]				
9.86161232e+01 9.73813213e+01 9.73813213e+01 9.88970697e+01 9.88970697e+01 9.87148658e+01 9.92579964e+01 9.92579964e+01 1.00490065e+02 1.01048677e+02 1.02713002e+02 1.02768204e+02 1.02034844e+02 1.02034844e+02 1.03011280e+02 1.02977747e+02 1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.05920001e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.1576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]				
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1.03925433e+02 1.04788987e+02 1.05699817e+02 1.05829782e+02 1.06967003e+02 1.07776132e+02 1.07765939e+02 1.08044013e+02 1.08448471e+02 1.00602431e+02 1.09527135e+02 1.05920001e+02 1.09988505e+02 1.10761195e+02 1.12160309e+02 1.08808186e+02 1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]				
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1.08808186e+02 1.14340482e+02 1.14278209e+02 1.14278209e+02 1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]				
1.13576422e+02 1.14142602e+02 3.65664730e+00 1.16266420e+02 1.16052482e+02 1.17353337e+02 3.07776093e+01 1.22365699e+02 3.07776093e+01 1.23895581e+02]]				
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3.07776093e+01 1.23895581e+02]] 3-D noints				
3-D noints				1.22303033ET02
Multiple Views	3-D noints	-	-	
indiciple views		Multinl	e Views	



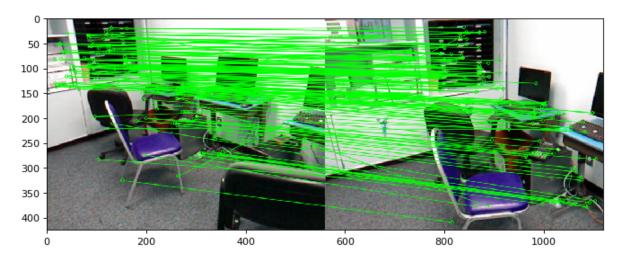




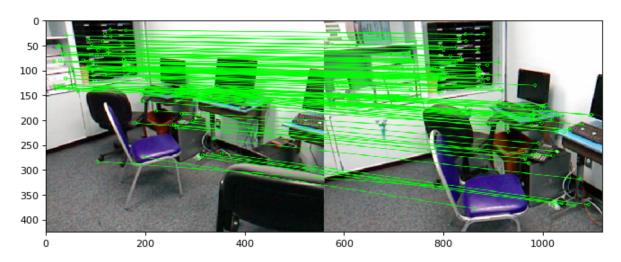


In [60]: SFM('HW4_data/b1.png','HW4_data/b2.png')

Before RANSAC:



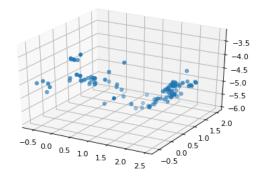
After RANSAC:

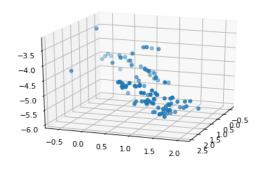


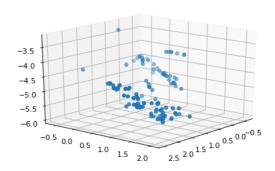
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Rotation:
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 [-0.31575505
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 [-0.40006709]
 [ 0.83310131]]
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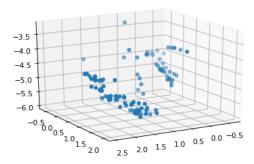
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-111.55527188 -130.62476232 -121.2200933 -121.2200933 -127.19885595
-126.88696733 -128.11421861 -128.51020978 -123.55128102 -129.05904501
  -89.96929723 -132.65231117 -133.38593001 -134.2927956 -130.46786056
-128.77060199 -133.26368033 -135.69493431 -135.67381292 -136.59401815
-133.20721124 -140.09359427 -129.81603709 -140.04699931 -138.7482673
-143.65566811 -134.84644683 -142.18699036 -141.91894447 -146.99395446
-138.16006158 -147.08633735 -140.7740706 -142.74241901 -151.06096448
-151.06096448 -80.74530679 -151.99797083 -152.6450507 -158.73643098
-150.51551097 -155.43926349 -155.52163312 -165.32994091 -165.32994091
-156.75791695 -158.28448591 -159.77032964 -135.62364404 -135.69493431
-165.55152769 -159.9070056 ]]
```

------Multiple Views-----



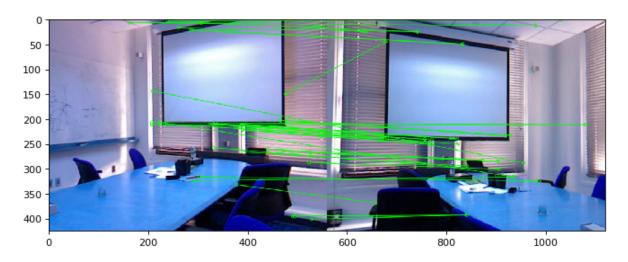




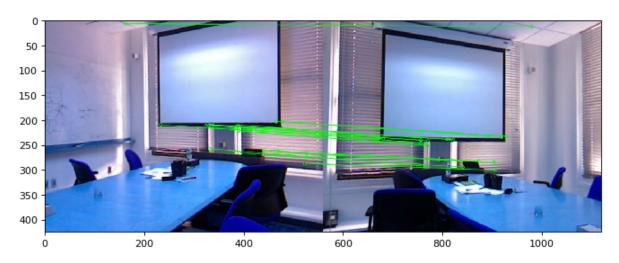


In [61]: SFM('HW4_data/c1.png','HW4_data/c2.png')

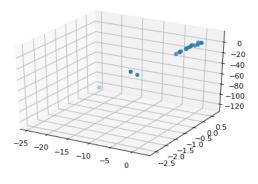
Before RANSAC:

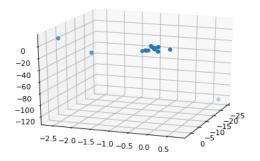


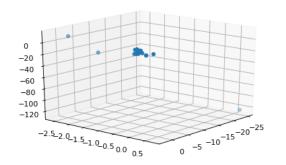
After RANSAC:

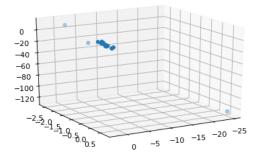


```
Essential matrix:
[[ 0.00473978  0.31054486  0.00603249]
[ 0.39721785 -0.03937412  0.58356854]
[-0.02344382 -0.6340427 -0.03253751]]
Rotation:
[[ 0.98971631 -0.01233748 -0.14251108]
[-0.02016788 -0.99835704 -0.05363276]
[-0.14161524 0.05595537 -0.98833907]]
Translation:
[[0.89833516]
[0.01519329]
[0.43904795]]
-115.59387625 227.74827855 -80.2156471 -13.95595786 -17.65960166
   77.50463325 116.14446292 -126.27579725 -131.61464713 -131.67502499
  -88.23975696 -88.10324334 -183.15595437 -284.55666144 -181.84326039
 -130.9417333 -130.46835824 -184.43690297 -184.43690297 -117.57086148
 -133.65320043 -112.47464312 -132.63487612 -360.33746922 -115.69036789
 -216.808904 -221.82889301 -183.02221441 -188.42973696 -255.33307392
 -459.68615832]
 -30.02040456 -429.95548317 -434.9502494 -441.16830446 -530.86961285
 -451.17702105 -16.06799168 -47.77756839 -78.6934831 -78.04416059
 -648.60761944 -650.05281099 -38.16576152 -456.4039462 -555.65010178
 -454.60412717 -454.58580578 -468.34917674 -702.8217101 -460.86960864
 -455.92873805 -478.48190455 -478.89993141 -478.89993141 -567.65941177
 -550.2422465 -445.1710836 -557.87338647 -199.14176043 -444.52172092
 -793.37876377 -794.34345493 -595.9366067 -560.88303002 -800.00547276
  -44.5684775 ]
[ -60.22288799 -63.27925004 -63.27925004 -41.36811194 -36.90139519
   -5.2423673 -68.17158411 -25.80445278 -37.36354146 -37.36354146
  -36.90139519 -43.73860275 -25.80445278 -15.90895302 -14.21119388
  -23.35303962 -24.23413022 -15.62050197 5.22831562 -17.75625954
  -25.23174918 -24.918104
                           -17.11356037 -17.11356037 -24.83428201
  -30.04488397 -39.26365225 -34.29479031 -15.58343108 -40.64246899
  -19.26720414 -19.26720414 -33.83520464 -34.29479031 -19.26720414
  -10.9937539 ]]
3-D points
```









SFM:

Structure from motion pipeline consists of finding 3D matching points. Initially find the matching points and then filter the weak matches using RANSAC. Compute the Essential matrix and decompose it to Rotation and Translation matrices. Calculate the 3D points from triangulation and matching. Add subsequent views and perform above steps repeatedly and do bundle adjustments to get the dense points reconstruction of the 3D scene.

Matchings:

Matchings are relatively better after performing RANSAC and filtering the weak matches.

Translation Matrix:

Translation vector is recovered along with the rotation matrix from the essential matrix. Translation matrix in this context refers to the position of the camera of one image with respect to another image. from the translation vector, we can estimate the positions of cameras with respect to each other. we can observe that the first value represents the lateral movement of the camera, second value represents the relative change in height and third value represents the relative change in depth stating whether the camera is moved closer or farther away from the scene.

Result:

If we observe the 3D plots we can observe that the matched points were plotted very well. Even the depth of the images were also relatively accurate in the 3d-plots from images. If we observe, in first two cases the matchings in the images are of varied depth and in the 3D plot we can observe that the points were distanct along Z-axis accounting the depth. In the last image pair, the matching was present relatively at the same depth around the projector screen, we can see a cluster of points in the last graph without much variation along the z-axis.

Finally, we can need more feature matches to construct the above images completely using 3D, as a result, more camera angles.