Problem 1

a. Intrinsic Parameters Matrices:

KI:

```
186.994         0      160.6481
      0   246.3474      30.44049
      0         0             1
```

TI:

```
 0.48573708   -0.87410361   -0.0015373376    15.254536
0.013919079   0.0064612491     0.72411669    1.5228312
-0.63294308   -0.35175173     0.015305186   -2489.5116
          0             0               0            1
```

Kr:

```
179.7206         0      145.4806
       0    245.743      19.03813
       0         0             1
```

Tr:

```
 0.48573708   -0.87410361   -0.0015373376    15.254536
0.013919079   0.0064612491     0.72411669    1.5228312
-0.63294308   -0.35175173     0.015305186   -2489.5116
          0             0               0            1
```

b. Error-values computed:

Error w.r.t Ground Truth:

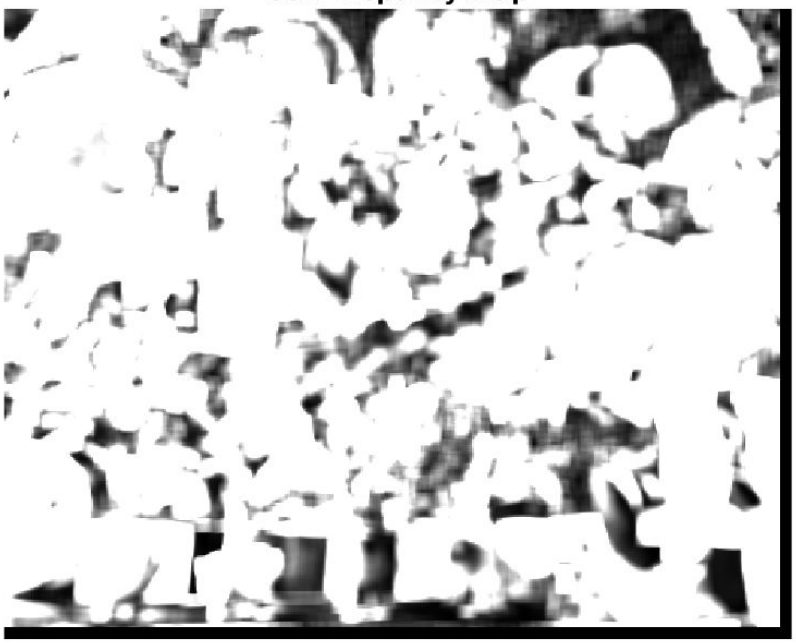
```
 3.0937
 2.3601
0.77193
 1.5797
 4.7098
 4.1762
 3.6708
 3.9812
  5.091
 4.5356
```

Error Statistics:

```
Min Error
0.77193
Max Error
5.091
Error Mean
3.397
Error Std
1.4249
```

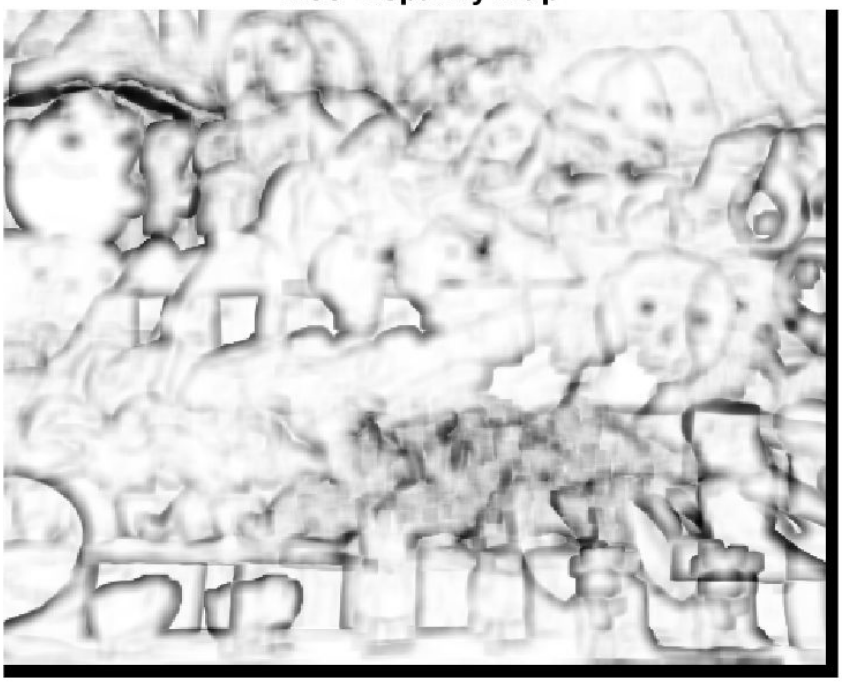
Problem 2

SSD Disparity Map



CC Disparity Map

NCC Disparity Map



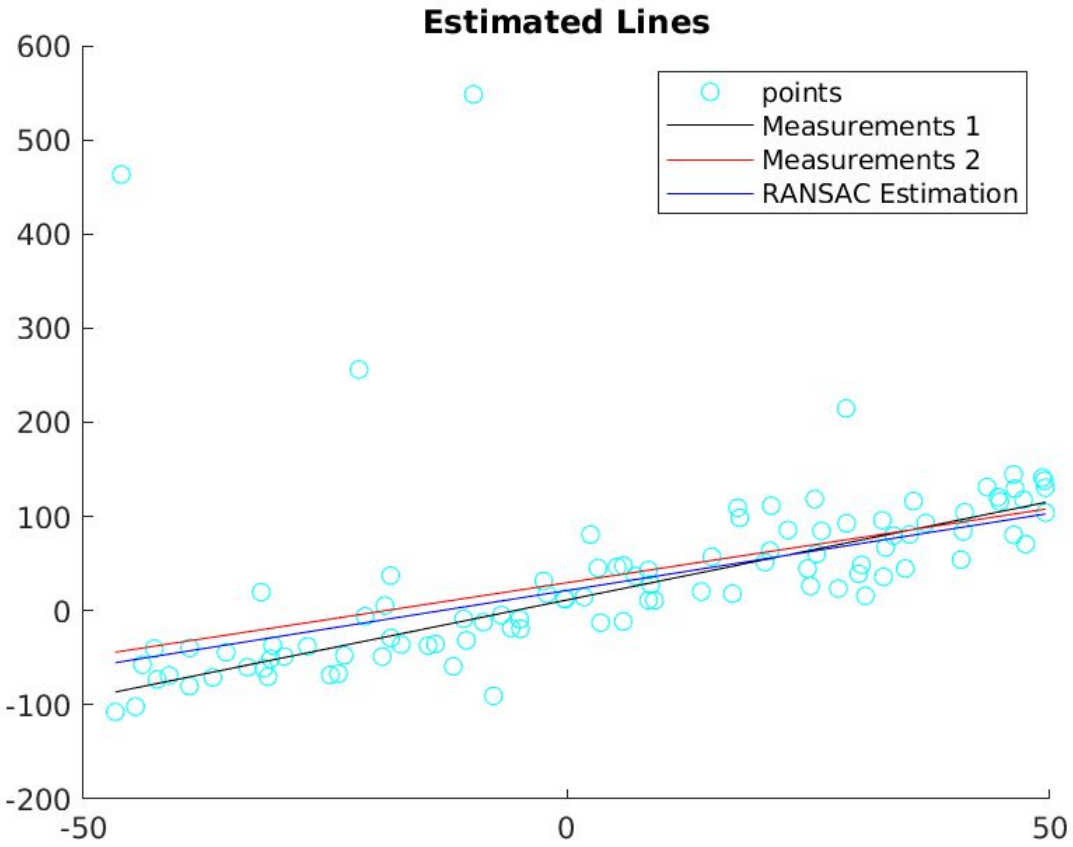
Error Statistics:

Method	Mean Error	Max Error	Min Error	Error Std	Running Time (seconds)
SSD	3.5830	34.3012	3.1528e-06	4.3162	0.382920
CC	2.6292	30.1133	1.1017e-06	3.6097	0.413366
NCC	0.6582	0.9862	4.2581e-05	0.1819	1.044601

Window size taken: (7x7) (yielded better result)

Among the three methods above, NCC seems to be the best if we consider the error percentage, but if we focus on speed both SSD and CC methods are comparatively faster than NCC.

Problem 4



Method	Line Parameter (W)
Measurements 1	[2.09203, 11.3271]
Measurements 2	[1.57843, 29.6492]
RANSAC Estimation	[1.64146, 21.4035]

Ransac Parameters:

Threshold: *60 (selected randomly visualizing for each value taken)*
Number of points taken: *10*

EXTRA CREDIT

Using the MATLAB camera toolbox, the extracted results from the given checkerboard images are shown below. The intrinsic parameters for both left and right cameras along with the extrinsic parameters giving the transformation for points in the right camera to those in the left camera frame are given below.

```
Stereo calibration parameters after optimization:


Intrinsic parameters of left camera:

Focal Length:          fc_left = [ 742.33151   758.24496 ] ± [ 96.76028   99.32829 ]
Principal point:       cc_left = [ 397.25962   206.56216 ] ± [ 32.38926   33.84856 ]
Skew:             alpha_c_left = [ 0.00000 ] ± [ 0.00000  ]   => angle of pixel axes = 90.00000 ± 0.00000 degrees
Distortion:            kc_left = [ -1.60980   11.01852   -0.01071   -0.06483  0.00000 ] ± [ 0.82016   10.72604   0.03393   0.03177  0.00000 ]


Intrinsic parameters of right camera:

Focal Length:          fc_right = [ 528.64586   590.79207 ] ± [ 83.79418   80.16572 ]
Principal point:       cc_right = [ 430.69284   188.87239 ] ± [ 86.24145   33.79906 ]
Skew:             alpha_c_right = [ 0.00000 ] ± [ 0.00000  ]   => angle of pixel axes = 90.00000 ± 0.00000 degrees
Distortion:            kc_right = [ -0.17372   -0.78303   -0.00325   -0.11540  0.00000 ] ± [ 0.46076   1.51601   0.01790   0.06528  0.00000 ]


Extrinsic parameters (position of right camera wrt left camera):

Rotation vector:             om = [ 0.00414   -0.11644  -0.00576 ] ± [ 0.04669   0.14886  0.00747 ]
Translation vector:           T = [ -183.24627   114.71485  -656.35000 ] ± [ 106.16727   42.59277  212.75900 ]


Note: The numerical errors are approximately three times the standard deviations (for reference).
```

Intrinsic Parameter Matrices (Using the above calibration output to be used in Prob3)

```
Kl = [742.33151   0           0;
      0           758.24496   0
      397.25962   206.56216   1];
Kl = Kl';

Kr = [528.64586   0           0;
      0           590.79207   0
      430.69284   188.87239   1];
Kr = Kr';
```

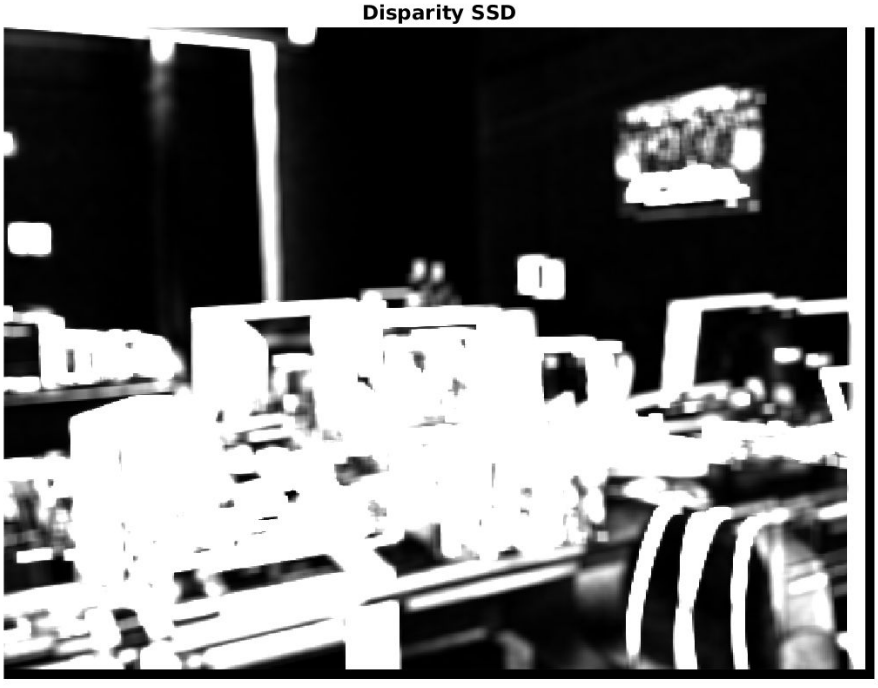
Problem 3

3D point cloud

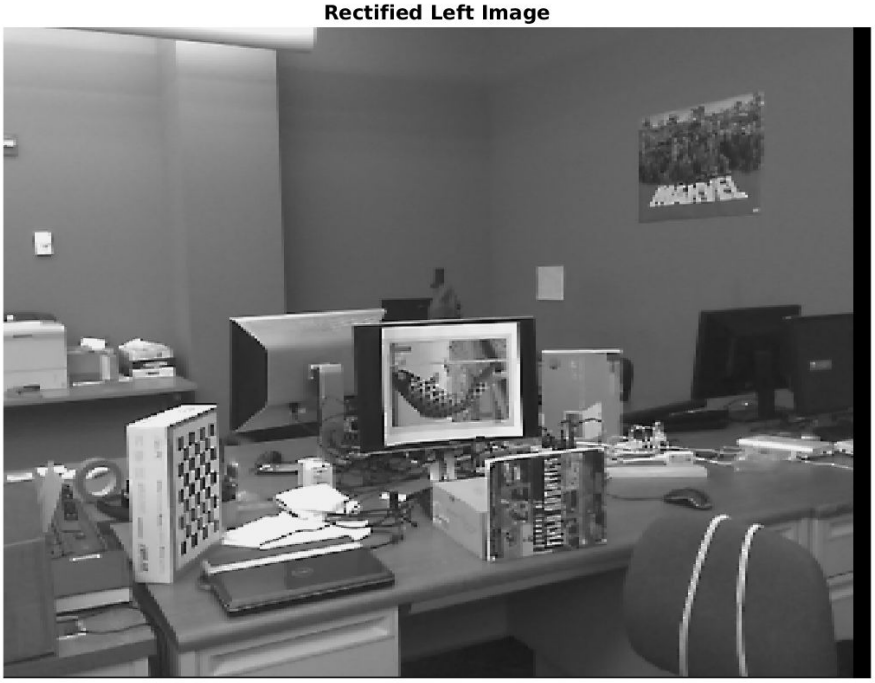
Disparity NCC

Disparity CC

Disparity SSD



Rectified Left Image



Rectified Right Image