TTK4255 - Assignment 2 by Dinosshan Thiagarajah

1 Image undistortion

In [1]:

```
import matplotlib.pyplot as plt
import numpy as np
```

In [2]:

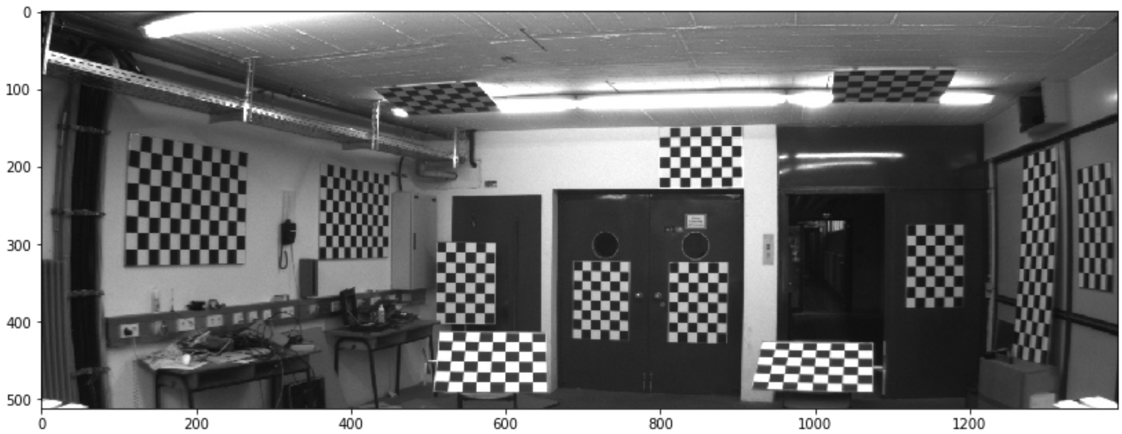
```
# Kitti parameters
fx = 9.842439e+02
fy = 9.808141e+02
cx = 6.900000e+02
cy = 2.331966e+02
k1 = -3.728755e-01
k2 = 2.037299e-01
k3 = -7.233722e-02
p1 = 2.219027e-03
p2 = 1.383707e-03
```

In [3]:

```
# Load images and visualize
img = plt.imread('data/kitti.jpg')
plt.figure(figsize=(14,10))
plt.imshow(img)
```

Out[3]:

```
<matplotlib.image.AxesImage at 0x7f51fc2dd5c0>
```



In [4]:

```
# Intrinsic parameter matrix
K = np.array([\
[fx,0,  cx],\
[0, fy, cy],\
[0, 0,  1]])

# Perspective projection matrix
PI = np.concatenate((np.eye(3),np.zeros((3,1))),axis=1)

# dst = np.linalg.pinv(K@PI)@np.array([[u_dst],[v_dst],[1]])
# x_dst = dst[0]
# y_dst = dst[1]
```

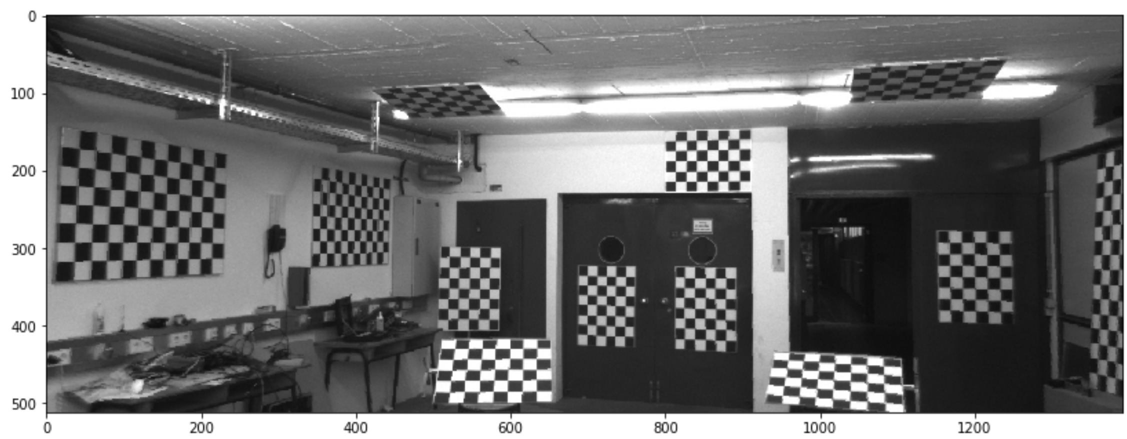
Task 1 a)

In [5]:

```
# Undistort image using extended camera model with distortion terms
def undistort_image(img, fx, fy, cx, cy, k1, k2, k3, p1, p2):
    img_undistorted = np.uint8(np.zeros(np.shape(img)))

    for v_dst in range(np.size(img,0)):
        for u_dst in range(np.size(img,1)):
            # Inverting equations (1)-(2)
            x_dst = (u_dst-cx)/fx
            y_dst = (v_dst-cy)/fy

            # Compute the source image pixel coordinates under the distorted pin
hole model
            r = np.sqrt(x_dst**2+y_dst**2)
            delta_x = (k1*r**2+k2*r**4+k3*r**6)*x_dst+2*p1*x_dst*y_dst+p2*(r**2+
2*x_dst**2)
            delta_y = (k1*r**2+k2*r**4+k3*r**6)*y_dst+p1*(r**2+2*y_dst**2)+2*p2*
x_dst*y_dst

            # Equations (3)-(4)
            u_src = cx+fx*(x_dst+delta_x)
            v_src = cy+fy*(y_dst+delta_y)

            if u_src <= np.size(img,1) and v_src <= np.size(img,0):
                img_undistorted[v_dst,u_dst,:] = img[int(v_src),int(u_src),:]
    return img_undistorted

# Visualize undistorted image
img_undistorted = undistort_image(img,fx,fy,cx,cy,k1,k2,k3,p1,p2)
plt.figure(figsize=(14,10))
plt.imshow(img_undistorted)
```

Out[5]:

<matplotlib.image.AxesImage at 0x7f51fbe97cf8>



Task 1 b)

Image seen by a camera with different intrinsic parameters can be generated by first undistort a distorted image as done above, and then distort the image with new intrinsic camera parameters. In order to distort the image (x,y) has to be calculated by inverting equations (3)-(4). Then pixel coordinates calculated by equations (3)-(4) with new parameters.

Task 1 c)

Since the Z is not changed when just the orientation is changed, image seen by a camera at different orientations can achieved by rotating the vectors spanning from projection center to each pixels on the image, and projecting to the image plane.

Task 1 d)

It is possible to translate the camera in x,y,z directions, but that means not all pixels will receive a value.
In general however, camera at different positions receive some information that is not entirely encapsulated by a
camera at a another location. This includes information about a different part of the world, and/or at different angles.

Geometric changes (scaling, rotation of objects) happens as well when capturing image from a different position, which is
not captured by a camera from another position.

2 Camera calibration

Task 2 a)

Intrinsic parameters: fx, fy, cx, cy, k1, k2, k3, p1, p2
Extrinsic parameters: checkerboards on the picture
There are 13 checkerboards in total, 6 extrinsic parameters per checkerboard, meaning 78 in total.

Task 2 b)

Advantages:

- Easy to print/make 2D calibration object in practice compared to 3D
  - it is important that the calibration object is very precise in its dimensions
- Easy to capture images of planar objects compared 3D, to calculate the instrinsic parameters accurately

Task 2 c)

Print

- imperfections on paper can affect accuracy and calibration
- easy to move around and capture images to cover the whole field of view

Screen

- no imperfections often on screen
- bad screen resolution can affect accuracy

Task 2 d)

There are 4 (cx,cy,fx,fy) intinsics and 6 (X,Y,Z,psi,theta,phi) extrinsics parameters to calculate
, in total 10 parameters to calculate. With two equations per correspondance, one would need atleast 5 correspondances to estimate the intinsics and extrinsics.

Task 2 e)

One case of ambigiousness is that one can achieve the same projection by either swapping fx and fy or just rotating the image by 90 degrees and obtain the same image.

Task 2 f)

One example is with a camera having radial distortion. During calibration, three images are captured (minimum requirement for Matlab calibration toolbox) arround the center. The reprojection can be good, but the calibration can miss the radial distortion part due to lack images from around the edges, which can lead to not compensating for the distortion.

A different case is that from 2 e). Even though the reprojection was accurate for the image in 2 e) for a certain set of parameters, this does not mean that a checkerboard with different position and orientation will be reprojected correctly with the same set of estimated parameters due to multiple solutions existing for calibration in 2 e).