Computer Vision
Assignment 3

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Question 1: Epipolar Geometry

Describe what test you used for deciding inlier vs. outlier. :

I have computed the distances of the points from the epipolar lines and used it to determine if it is an outlier or an inlier.

$$\widehat{\boldsymbol{x}}'^{T} \boldsymbol{F} \widehat{\boldsymbol{x}} = 0$$

$$cost(\boldsymbol{X}) = dist(\boldsymbol{x}, \widehat{\boldsymbol{x}})^2 + dist(\boldsymbol{x}', \widehat{\boldsymbol{x}}')^2$$

Lecture 14: Advanced Computer Vision: Prof Jia Bin Huang https://filebox.ece.vt.edu/~jbhuang/teaching/ece5554-4554/fa17/lectures.html

Here the lines l1 and l2 are computed using the existing points from image 1 and image 2 and premultiplying them with the Fundamental Matrix.

We know that

Epipolar line, L = F.x   Where F is the Fundamental Matrix and x is the point.

To find if a particular point in image 1 is an outlier

Step1: Find the corresponding point in image 2.

Step2: Pre multiply F by that point

```
lineTemp1 = F*pt2(i,:)';
```

Step3: Find distance of the point in image 1 from this line.

```
pointDistanceX1(i) = (abs(pt1(i,:)*lineTemp1)/sqrt(lineTemp2(1)^2+lineTemp2(2)^2)).^2;
```

Step4: Check if this is greater than a particular threshold to determine if the point is a outlier or not.

Display the estimated fundamental matrix F after normalizing to unit length:

unitF =

0.0000	-0.0001	-0.0249
0.0000	-0.0000	0.1859
0.0271	-0.1658	-0.9678

Plot the outlier keypoints with green dots on top of the first image plot(x, y, '.g');

Green -> Outliers
Red -> Inliers

Randomly select 7 sets of matching points. Plot the corresponding epipolar lines ('g’) and the points (with 'r+’) on each image. Show the two images (with plotted points and lines) next to each other.

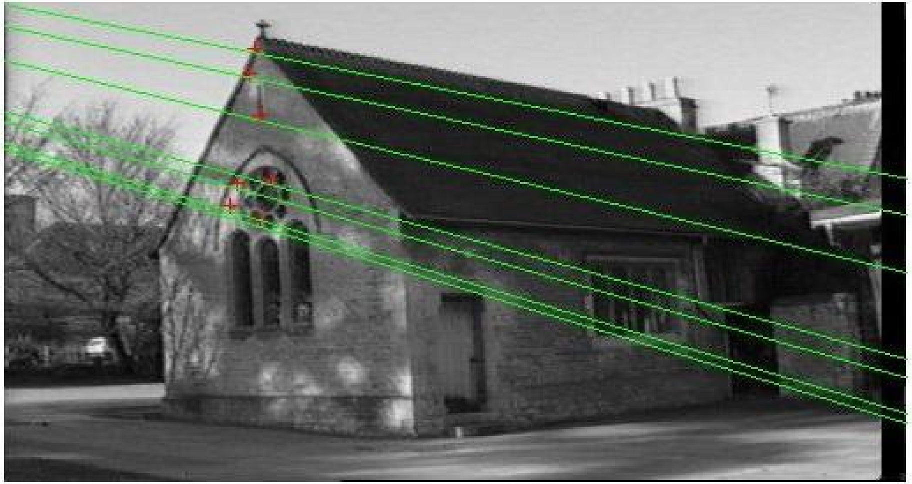


Image 1

Image 2

Question 2: Affine Structure from Motion

Include pseudocode in your report.

1. Get all valid tracked points using the KLT tracker
2. Normalise x and y co-ordinates to zero mean to remove the translation effect.
3. Create the measurement matrix

   ```
   D = [normX' ; normY'];
   ```

4. Find solution to the D = AX where A = motion matrix and X = Shape matrix

   Decompose using SVD `[U,W,V] = svd(D)`

5. Enforce rank = 3 for matrices U,W&V
6. Decompose U,V and W into A and X matrices. We are choosing the following decompositions

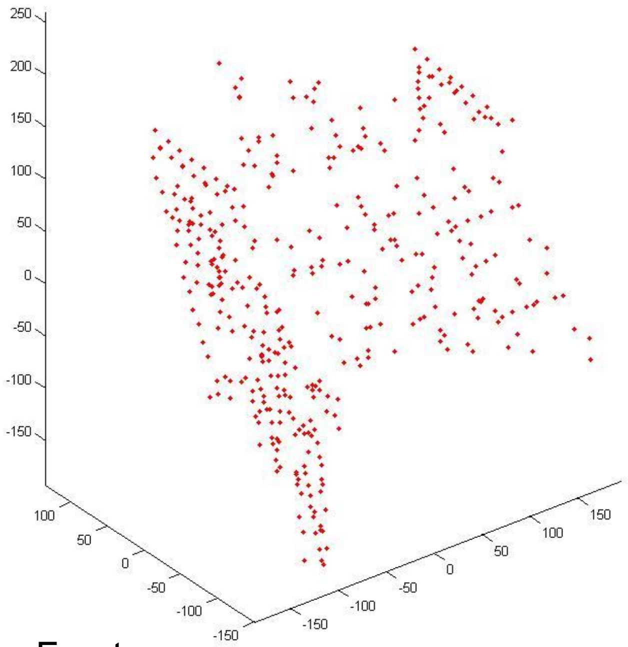
   $A = UW^{1/2}$ $X = W^{1/2}V$

7. Resolve Affine Ambiguity, using the Euclidean Constraints.

   -> AL = b, where L = CC^T and b = [.....0 0 1 0 0 1… 0 0 1] (Euclidean Constraint)

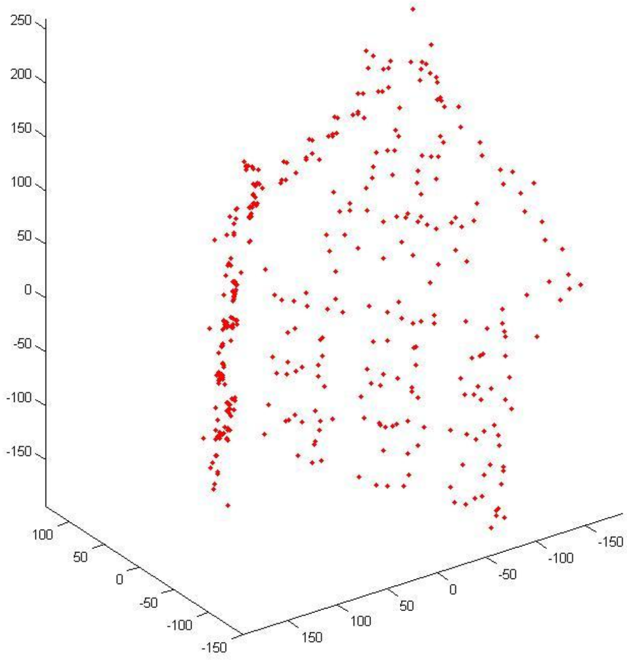
8. Use cholesky decomopistion to find the value of C.
9. Use A = AC and X = $C^{-1}X$

Plot the predicted 3D locations of the tracked points for 3 different viewpoints. Choose the viewpoints so that the 3D structure is clearly visible.

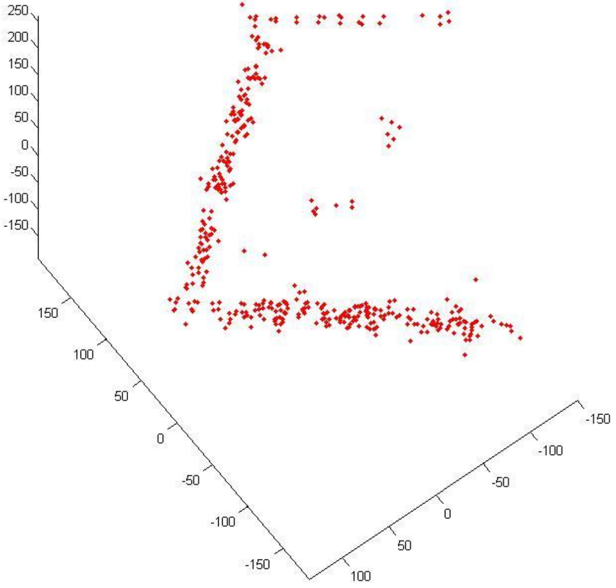


Viewpoint from Front

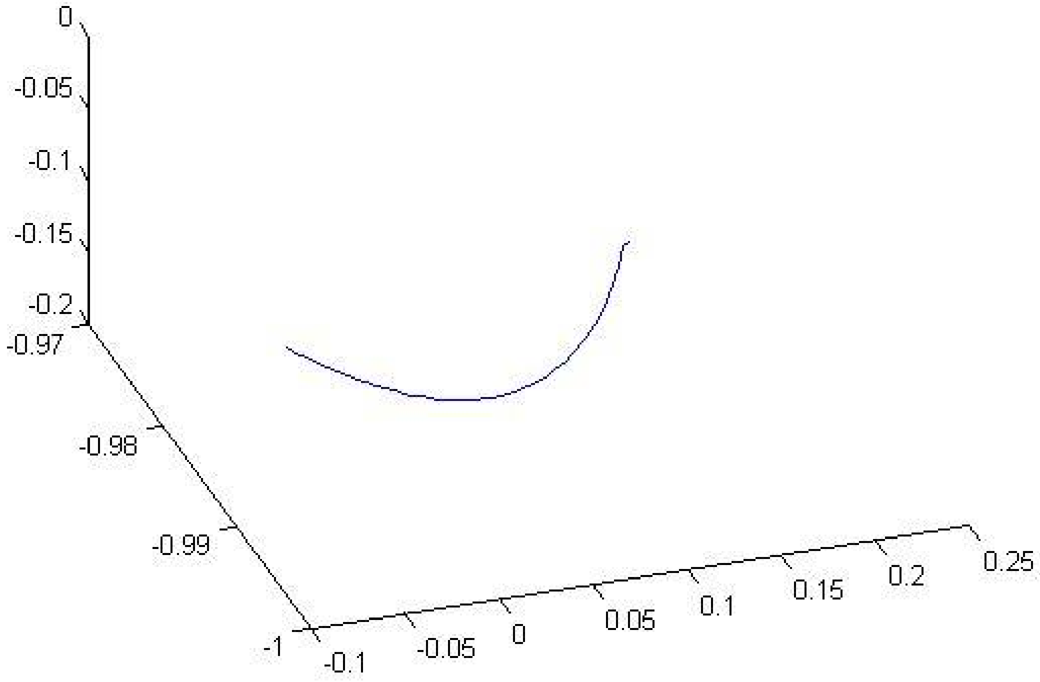
Viewpoint from Right Side of the Image, looking upwards.



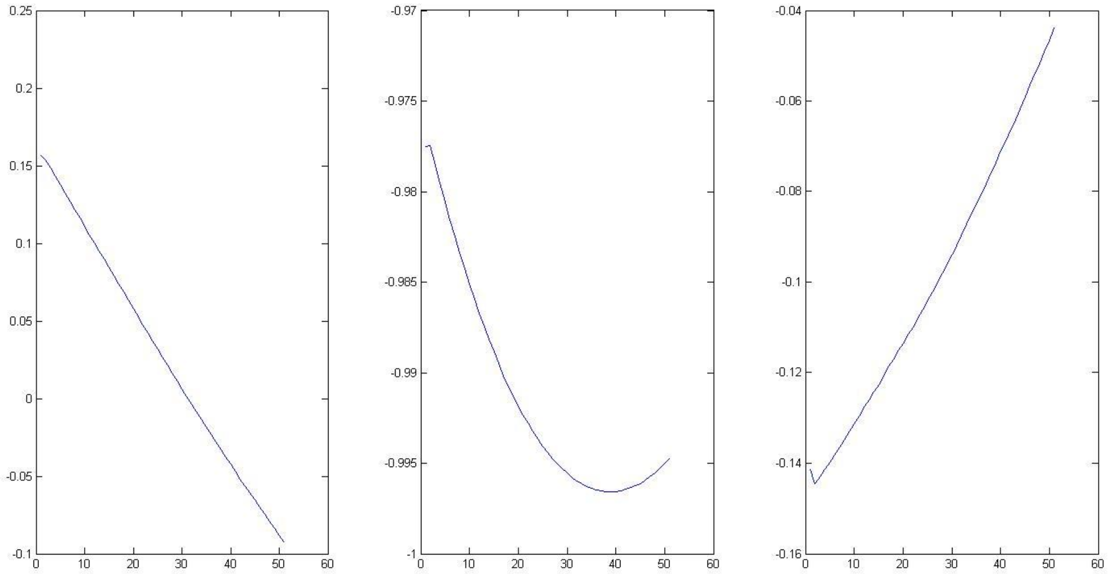
Viewpoint from Top of the Image,
looking downwards.



Plot the predicted 3D path of the cameras. The camera position for each frame is given by the cross product a_k = a_i x a_j. Normalize a_k to be unit length for consistent results. Give 3 plots, one for each dimension of a_k We provide the function `plotSfM.m` for visualizing the recovered 3D shape and camera positions in each frame.



Normalised X, Y and Z axis plot of camera’s motion.



Graduate Points

compare the results with **un-normalized** 8-point algorithm with RANSAC. For the inlier matches, report the averaged value of (x’^T F x)^2 (i.e. evaluating how well the recovered fundamental matrix F explains the inlier matches). Compare this value with the normalized 8-point algorithm.

Solution:
Following are the error values reported-

Averaged Error for Normalised 8-point Algorithm :

```
errorNormalised =
   18.4650
```

Averaged Error for UnNormalised 8-point Algorithm:

```
error2 =
   1052.7
```

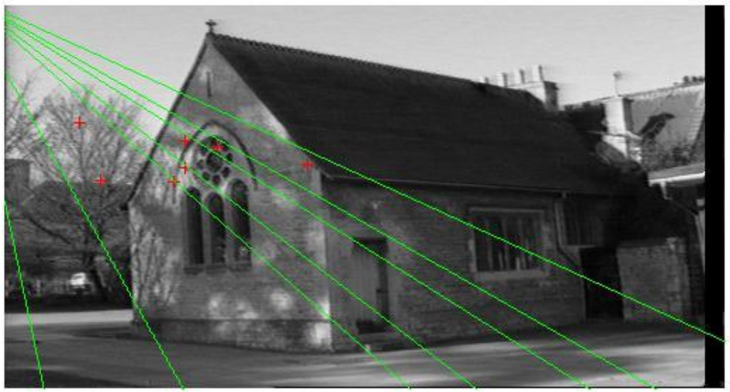
Following are the fundamental Matrices as obtained:-

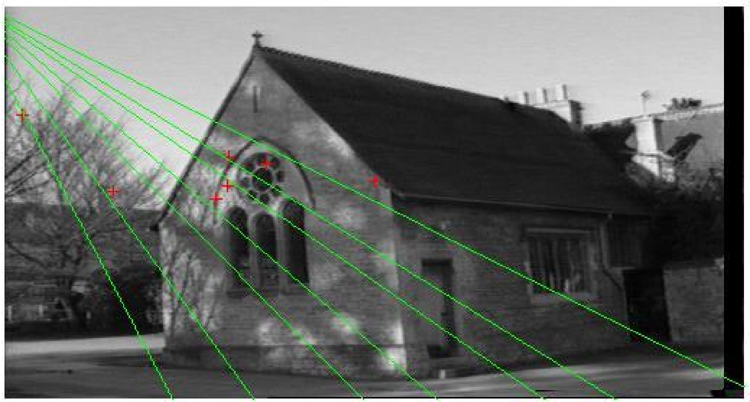
```
unitF_Normalised =
     -0.0000   -0.0001   -0.0274
     0.0001   -0.0001    0.2937
     0.0243   -0.2849   -0.9117


unitF_UnNormalised =
     -0.0015   -0.0202   -0.1925
     0.0275   -0.0088      0.6772
     0.1900   -0.6833      0.0104
```

This Shows that the normalised matrix will perform better as it has a better rank as compared to the Unnormalised Matrix.

The following figure shows the epipolar lines generated using the unnormalised 8-point algorithm. As we can see that the matches are not so great. This is because it is difficult to set a suitable threshold while using the un-normalised distance in images. This results in selection of a non-optimum Fundamental Matrix.

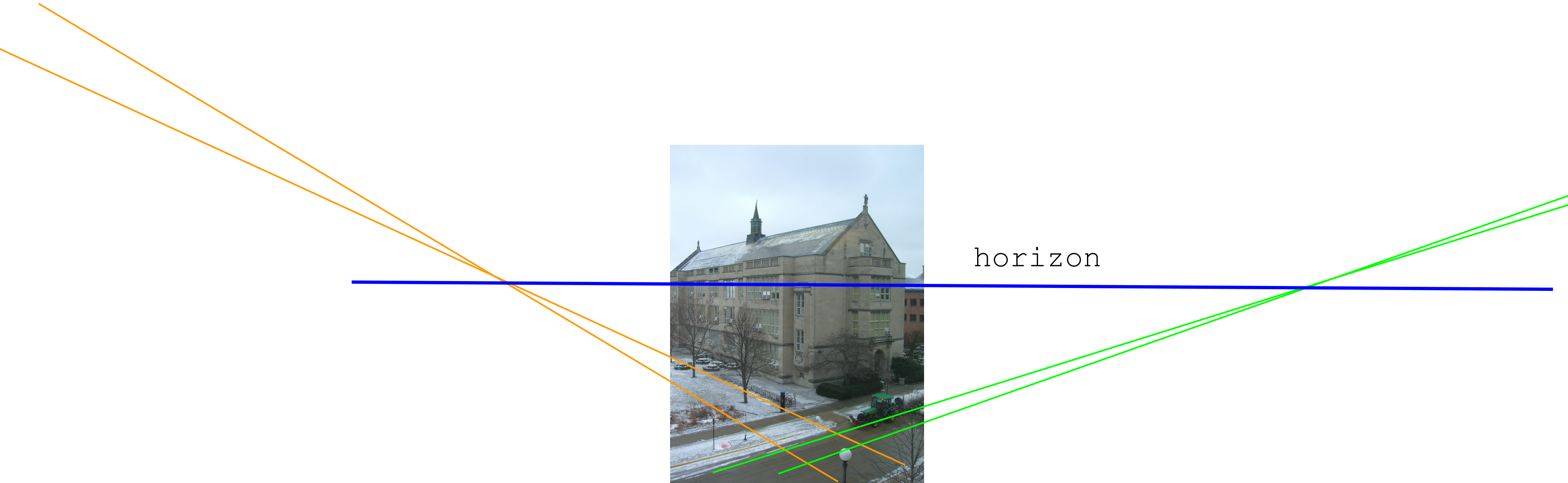
The points are far away from the epipolar lines, hence the average error increases.



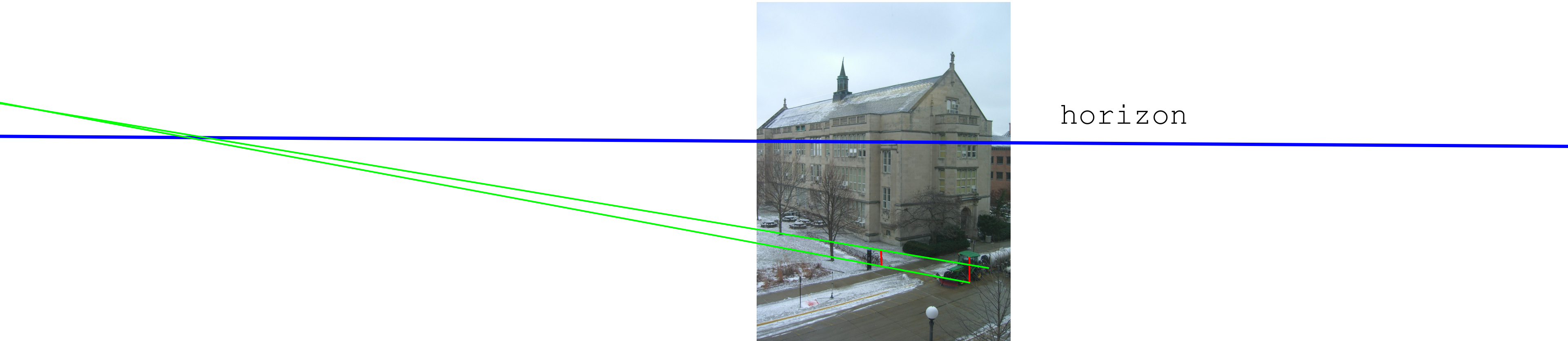


Graduate Points : Estimate the horizon and draw/plot it on the image. Assume that the sign is 1.65 meter. Estimate the heights of the tractor, the building, and the camera (in meters). This can be done with powerpoint, paper and a ruler, or Matlab.

1. Horizon



2. Sign

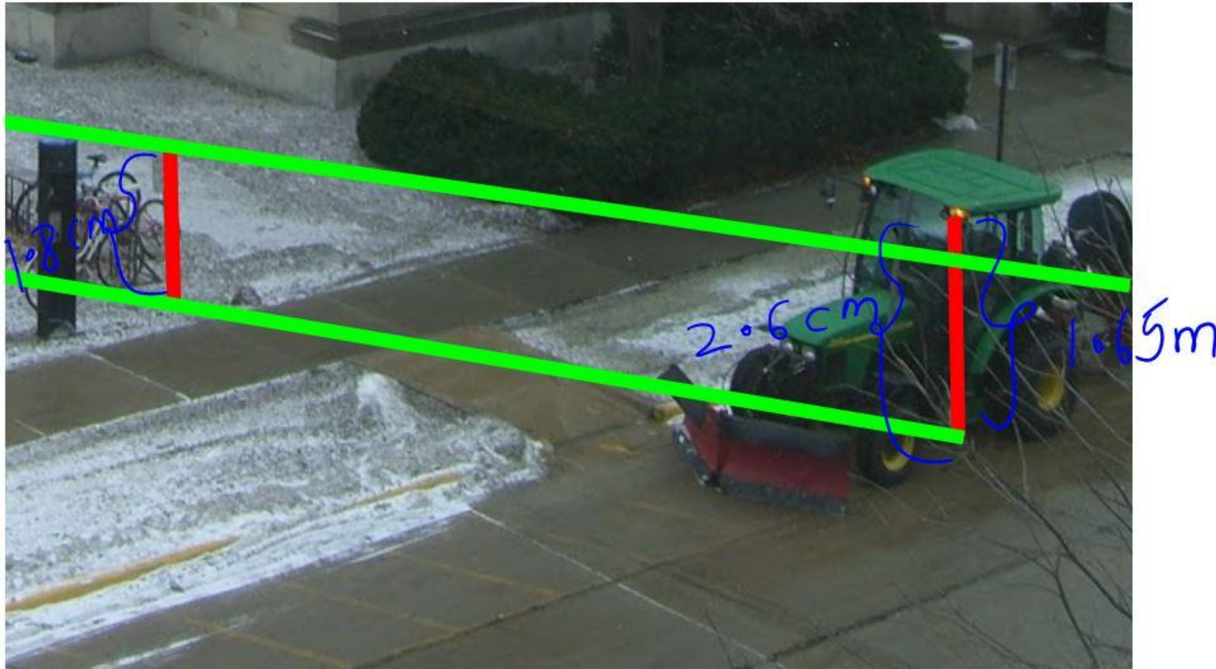


2. Sign

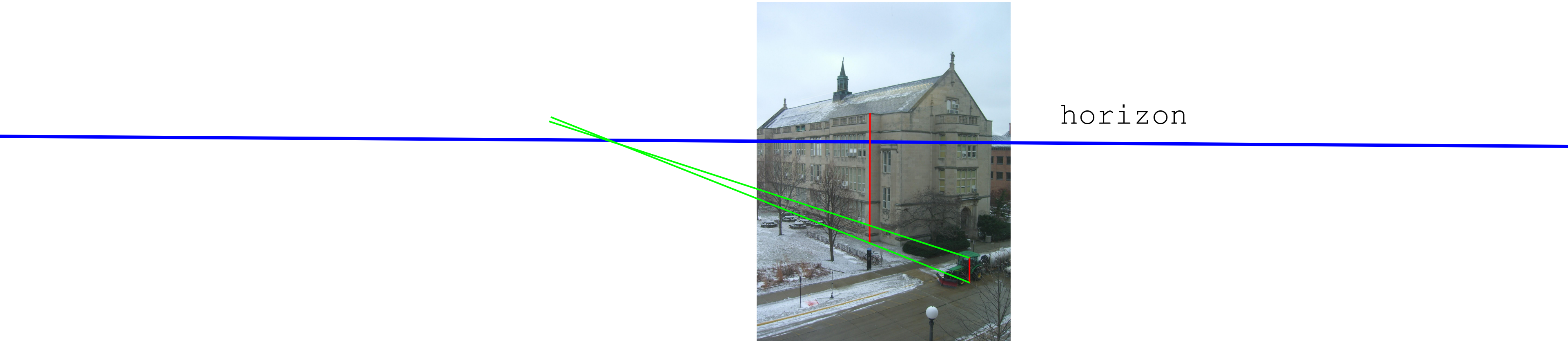
Tractor->
2.6cm -> 1.65m

Sign->
1.8cm -> ?

Height of the sign
= 1.65*1.8/2.6
=1.14 m



3. Building



3. Building

Tractor->
1.4cm -> 1.65m

Building->
7.5cm -> ?

Height of the building
= 1.65*7.5/1.4
=8.83 m