CS 763 (Spring 2019): Assignment 2

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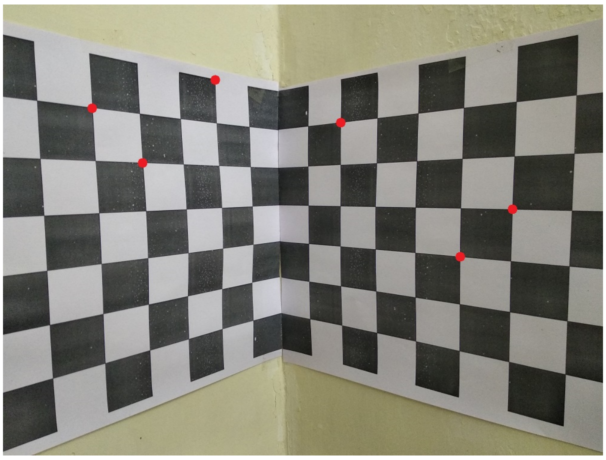
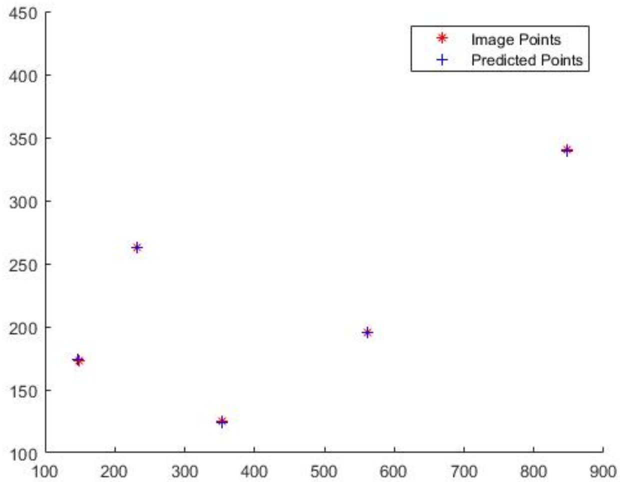
[All codes have been tested to be working on **MATLAB R2018b**]

Problem 1





Points used for calibration [and] Final Visualization of accuracy of the calibration

Reason for normalization

We do this for **numerical stability** in code.

First let's verify the normalization equations. DLT gives is the matrix P such that $x = PX$. Now, suppose we use the normalization transforms $\hat{x} = Tx$ and $\hat{X} = UX$, then

$$x = PX \implies \hat{x} = Tx = TPX = TPU^{-1}\hat{X}$$

This gives $\hat{P} = TPU^{-1} \implies P = T^{-1}\hat{P}U$ as mentioned in bullet 2.

Now that we've verified the equations, let's observe why we do this. Since x is a matrix containing 2D pixel coordinates and their homogeneous coordinates would be used during DLT, the pixel coordinates may be even in thousands but the third homogeneous coordinate is just 1. A similar possibility may also hold for X.

This eventually causes the matrix M (as described in lecture of DLT) to possibly have elements of different orders if not normalized, and hence $M^T M$ could be poorly conditioned resulting in potential buildup of numerical errors.

Thus normalization of x and X help to potentially avoid these numerical issues.

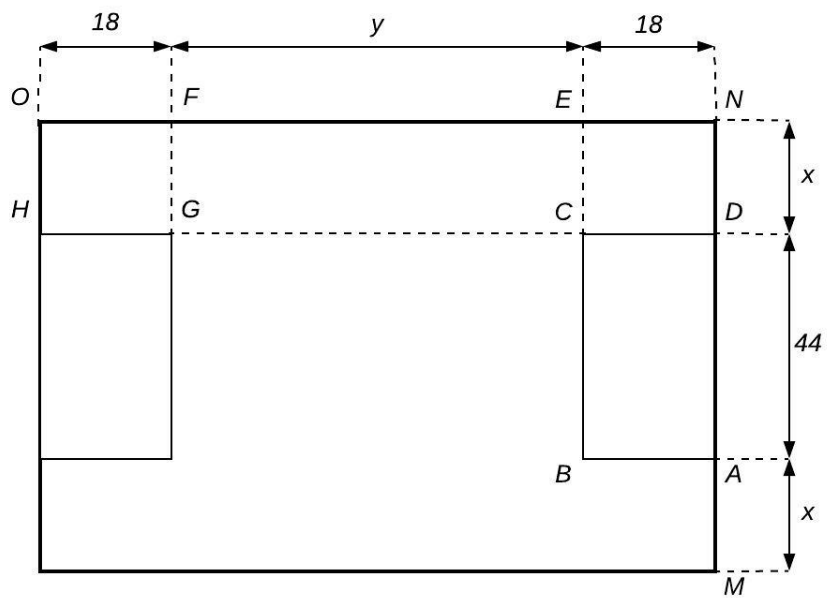
Problem 2

We approach this problem by finding out the homography corresponding to the transformation of the given image such that the transformed image has the coordinates $(0, 0)$, $(0, 18)$, $(44, 18)$, $(44, 0)$ measured in pixels; for the four corners of Dee. Under such a transformation (intuitively, the transformed image is called the top-view of the stadium), the dimensions of the original stadium (measured in yd) are same as the dimensions of playing area in this transformed image (measured in pixels).

So, after finding the homography matrix H, we find the transformed points of the 3 visible corners of the playing area and whose corresponding euclidean distances give the actual dimensions of the playing area as $74.477yd \times 116.841yd$.

[Please note that minor errors in measurements are possible due to inaccurate pixel coordinates of various points.]

Problem 3



We solve this problem by using the idea that cross-ratios remain the same between the given image and this view as shown above.

Assume the corresponding points in the **original (given)** image be denoted with $'$ like A as A' *etc.* The following pixel coordinates were measured in the given image,

$M' = (1022, 808)$, $A' = (1058, 719)$, $D' = (1124, 555)$, $N' = (1139, 517)$

$C' = (958, 534)$, $G' = (407, 467)$, $H' = (311, 453)$

Now, using cross ratio equality across the homography along $MADN$ gives

$$\frac{MD}{MN} \times \frac{AN}{AD} = \frac{M'D'}{M'N'} \times \frac{A'N'}{A'D'} \implies \frac{(x+44)^2}{44(2x+44)} \approx 1.57 \implies x \approx 15.222yd$$

Similarly using cross ratio equality along $DCGH$ gives

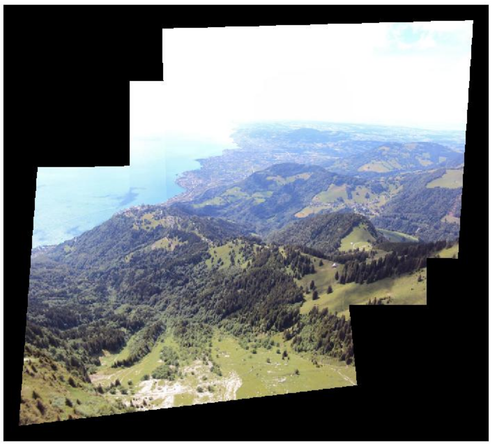
$$\frac{DG}{DH} \times \frac{CH}{CG} = \frac{D'G'}{D'H'} \times \frac{C'H'}{C'G'} \implies \frac{(y+18)^2}{y(y+36)} \approx 1.0354 \implies y \approx 79.335yd$$

This gives $MN = 2x + 44 \approx 74.44yd$ and $NO = y + 36 \approx 115.33yd$ which are approximately same as the values we found earlier in Problem 2.

[Please note that minor errors in measurements are possible due to inaccurate pixel coordinates of various points.]

Problem 4

Results

ledge.jpg	pier.jpg
	
monument.jpg	**hill.jpg**
	

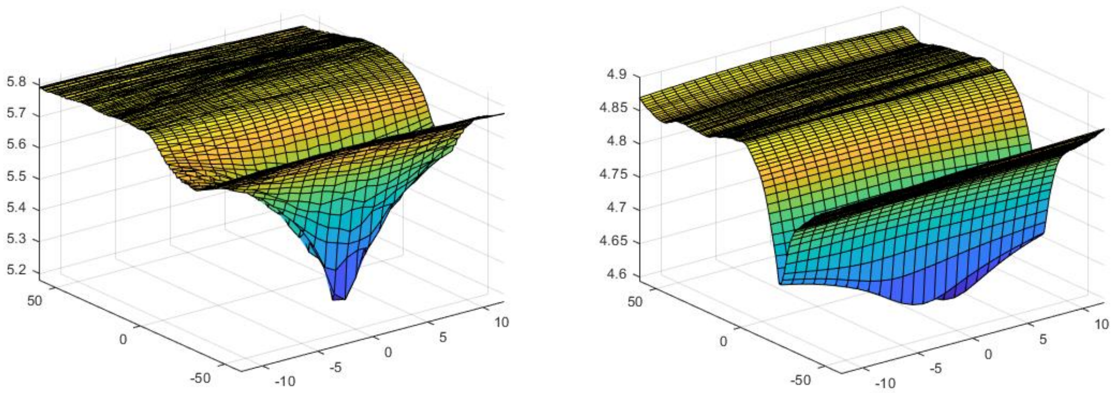
Own Sample Images

iitb-hostel.jpg	iitb-hostel-2.jpg
	

Problem 5

[Overall runtime for complete generation of all plots and code: 60.556 seconds on my PC]

Results



[Left]: Barbara & Negative-Barbara ; [Right]: Flash & No-Flash

The points of minimum entropy for both pairs are as follows:

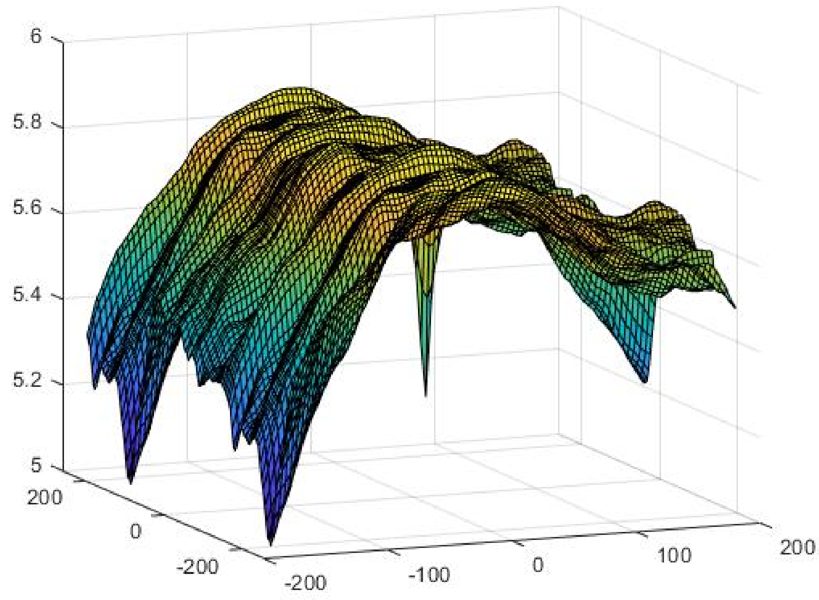
(barbara, negative_barbara) = $(23^\circ, 3)$

(flash, no_flash) = $(24^\circ, 3)$

For both pairs of images, we observe that results are pretty accurate and good.

[Results may slightly vary in each run due to random noise added to the image in every run.]

Misaligned minimum case

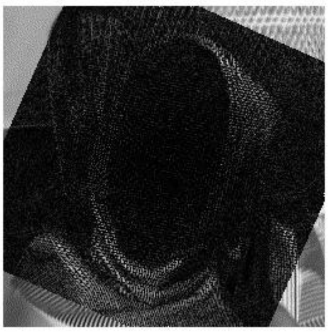


(The above plot for Barbara and its negative over rotation varied in range $[-180, 180]$ and translation in range $[-260, 260]$ with step size 4 justifies the below argument. The pointed local minima in the middle is the same minima found earlier).

When the overlap region between the two images is very small, the distribution can possibly have very low entropy. This is because, say we have only one point of overlap, then only one point exists in histogram and entropy is zero. In other words, if the translation and rotation parameters are in such a way that the actual overlap region of the two images is small, the entropy can falsely be small.

Image Alignment

I wasn't sure what this part of question was expecting. I had reconstructed (rotated and translated) according to the minimum entropy parameters and then produced two images, one in which they were alpha-blended with equal alphas and two, in which the difference of the two images is taken. We can see both the images in the output folder.



Difference Images on alignment: [Left]: Barbara & Negative-Barbara ; [Right]: Flash & No-Flash

Specifically, the above difference images being mostly black is indicating that the alignment was pretty good.