CS763 (Computer Vision)
Spring 2019
Assignment 2

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Contents

Answer 1

After applying the method, we got the following results.

$$P = \begin{bmatrix} 44.0619 & -4.8680 & -42.6856 & 333.9502 \\ -5.3817 & -62.0823 & -11.2133 & 468.7914 \\ -0.0276 & -0.0130 & -0.0549 & 1.0000 \end{bmatrix}$$

$$K = \begin{bmatrix} 931.3768 & -19.1748 & 301.6476 \\ 0 & -925.7055 & 397.5172 \\ 0 & 0 & 1.0000 \end{bmatrix}$$

$$R = \begin{bmatrix} -0.8931 & -0.0038 & 0.4499 \\ 0.0962 & -0.9785 & 0.1827 \\ 0.4395 & 0.2064 & 0.8742 \end{bmatrix}$$

$$X_0 = \begin{bmatrix} 6.4043 \\ 4.4811 \\ 13.9232 \end{bmatrix}$$

The Root Mean Squared Error between the $2D$ points marked by us and the estimated $2D$ projections of the marked $3D$ points = **1.384398**.

We know that if the Condition number of a matrix A $(= ||A|| * ||A^{-1}||)$ is large, the matrix is ill-conditioned, so it is close to being singular. And normalizing the matrix decreases the condition number.

Here, the matrix M on which we are finding eigen-values to calculate the projection matrix P depends on the coordinates of both image (x) and real world (X). So, if x and X are not normalized, the matrix M will be ill-conditioned and we won't get accurate results for projection matrix P.

Figure 1: The red dots correspond to the marked points used for finding the SVD and performing DLT. The yellow circles correspond the the predictions for those points. The cyan circles correspond to the predictions for the points that were **not** used for calculating P.

Answer 2

Given information is that the dimension of the outer Dee (or box) is always $18yd$ x $44yd$. Obtained length and width of the playing area using Homography Transform is **106.56yd** and **76.19yd** respectively.

The Homography transform is applied between the real co-planar football pitch (assuming z = 0) and the given image. The pixel coordinates for the outer Dee as well as the corners (three of which are visible) are calculated using $impixelinfo$ in MATLAB and the four outer Dee points are used to compute the homography transform, which is then applied to the corners to get their real positions on the pitch and thus the length and width of the pitch are acquired.

Answer 3

Given information is that the dimension of the outer Dee (or box) is always $18yd$ x $44yd$.

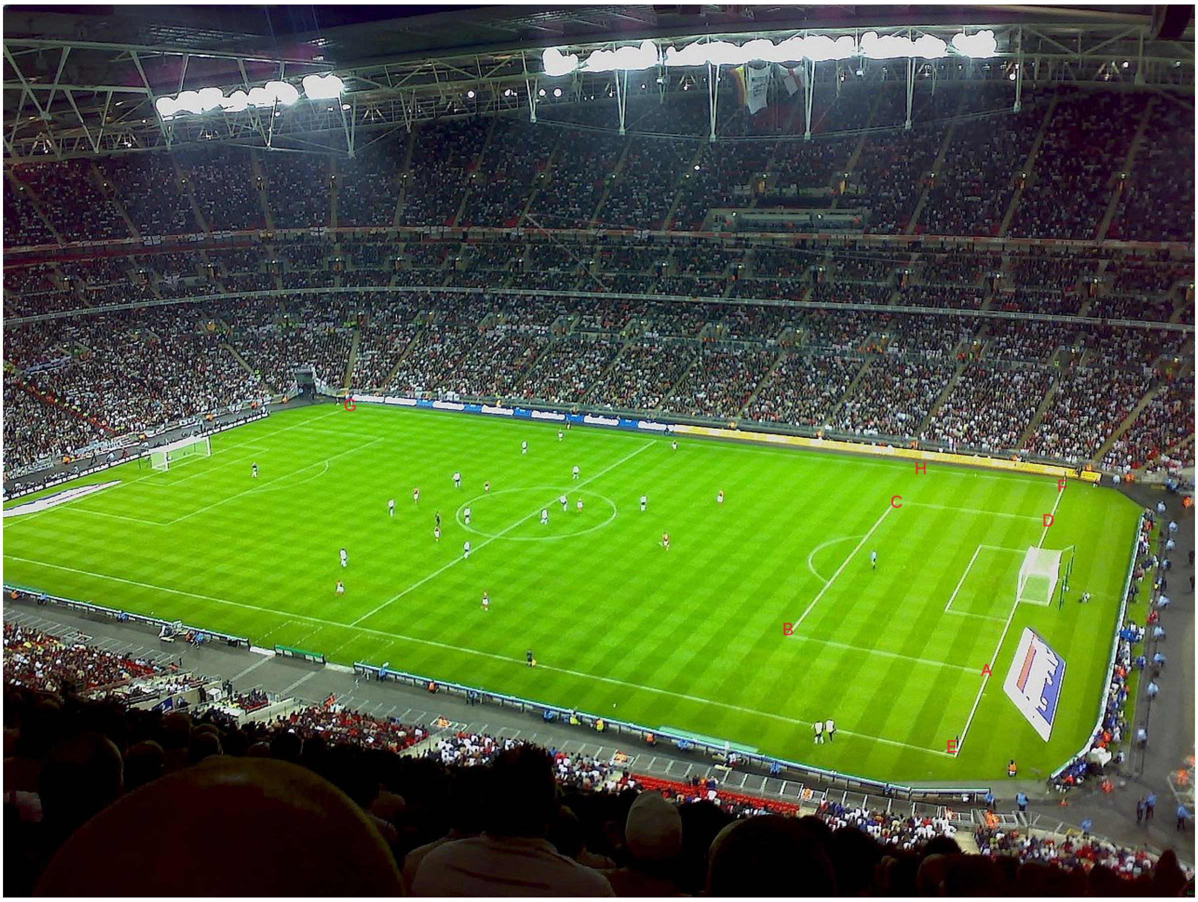

Figure 2: Points A, B, C, D, E, F, G, H are marked on image

Let us label the vertices of the outer Dee points and the corners as done in the image above. On the real football pitch, we know that AB, DC, FG are sets of (horizontal) parallel lines along the length of the pitch and BC, AD, EF are (vertical) parallel lins along the width of the pitch. So, **AD = BC = 44yd** and **AB = CD = 18yd**

We represent their corresponding image points by A', B', ... , G'.

Using $impixelinfo$ from MATLAB, we computed the pixel coordinates of the corresponding image points:

$A' = (1061, 721)$, $B' = (845, 682)$, $C' = (962, 537)$, $D' = (1126, 559)$,
$E' = (1024, 813)$, $F' = (1142, 519)$, $G' = (374, 436)$

First we compute the Vanishing Point (V'_v) for vertical set of lines using intersection point of B'C' and A'D' in pixel coordinates. $V'_v = (1305.8, 110.97)$. We can calculate all distance in image plane as we know pixel coordinates of all required points.

We calculate DF, using cross ratios for A, D, F and V_v

$$\frac{AF}{DF} = \frac{A'F'}{A'V_v'} : \frac{D'F'}{D'V_v'}$$

$$\frac{AD + DF}{DF} = \frac{217.63}{657.31} : \frac{43.08}{482.75}$$

$$DF = 16.24yd$$

Similarly we calculate EA, using cross ratios for E, A, D and V_v

$$\frac{ED(= EA + AD)}{AD} = \frac{E'D'}{E'V_v'} : \frac{A'D'}{A'V_v'}$$

$$EA = 15.95yd$$

So, width of the pitch is EF = EA + AD + DF = **76.19yd**

To find Vanishing point (V_h') for horizontal set of lines using intersection of F'G' and C'D' in pixel coordinates. $V_h' = (-2617.6, 56.81)$.

Now to use cross ratios, we first find intersection point (H') of B'C' and F'G'. So, in real coordinates, $ABHF$ is rectangle and so **FH** = **AB** = **18yd**. In pixel coordinates , we got $H' = (989.80, 502.55)$

To calculate FG, using cross ratios for F, H, G, V_h

$$\frac{FG}{HG} = \frac{F'G'}{F'V_h'} : \frac{H'G'}{H'V_h'}$$

$$\frac{FG}{FG - FH} = \frac{772.47}{3787.9} : \frac{619.38}{3634.8}$$

$$\mathbf{FG = 109.46yd}$$

So, the values obtained are **width** of pitch = **76.19yd** & **length** of pitch = **109.46yd**

Answer 5

Barbara

Output Images

Figure 3: Fixed Image

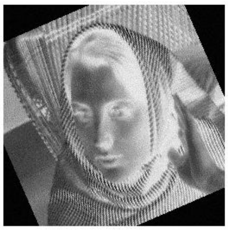

Figure 4: Moved Image

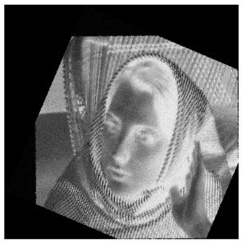

Figure 5: Registered Image

Plots

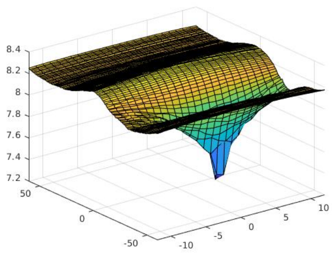

Figure 6: Overall Plot

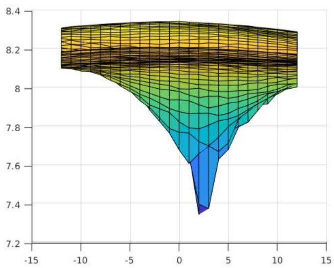

Figure 7: Translation Plot

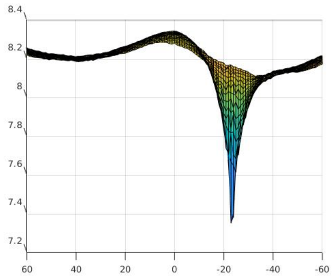

Figure 8: Rotation Plot

Flash

Output Images

Figure 9: Fixed Image

Figure 10: Moved Image

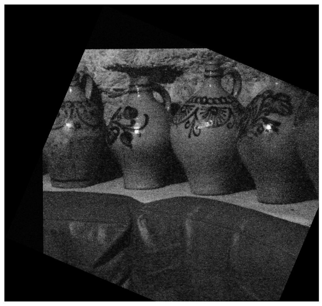

Figure 11: Registered Image

Plots

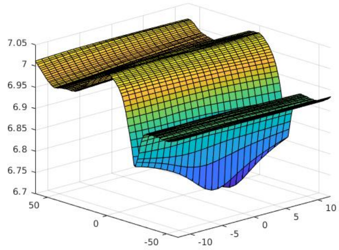

Figure 12: Overall Plot

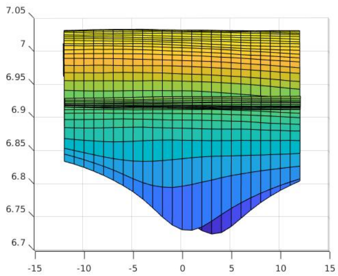

Figure 13: Translation Plot

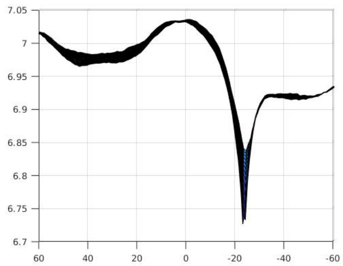

Figure 14: Rotation Plot

From the above graphs, we can see that the graphs with respect to both translation and rotation were very sensitive near the minimas for Barbara as the value of Entropy changes steeply around the minima. On the other hand, for Flash images, we see that the value of Entropy is somewhat insensitive to translation as the graph has a slightly flatter valley close to the minima. Also, we see that there are actually two local minimas in the plot. So, we choose the value of translation corresponding to the global minima by taking lesser of the two values.

If we keep the translation limit in the brute force search higher (in our case, -120 to 120), we see that beyond a certain magnitude of translation limit, the joint entropy starts to decrease and at one point even gets lower than that at the true minimum, i.e. 3px. This is clear from the plots that follow. In the image (Figure 15), the output image is clearly misaligned and yet, the joint entropy is lesser.

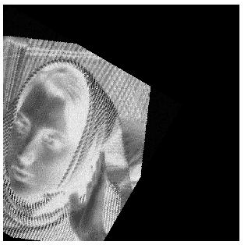

Figure 15: Misaligned Photo

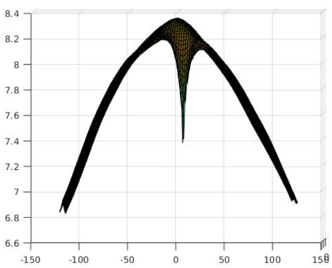

Figure 16: Translation Plot

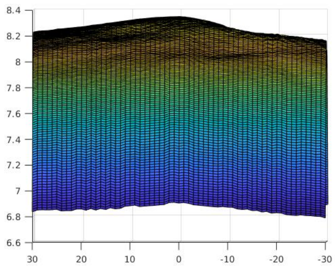

Figure 17: Rotation Plot