

# Assignment 2

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## 1 Introduction

In this task, a basic image stitching system is developed to create a single panoramic image.

### 1.1 Select Common Points on Images

Using matplotlib ginput function, user clicks common points for two images sequentially. In the code, clicked points are stored as variable and ginput function is commented in order to make experiments fast and consistent. Later on, common points pairs, used for homography estimation.

### 1.2 Homography Estimation

#### 1.2.1 Normalizing Points

Before homography estimation, points pairs are normalized for each corresponding image. This is made by, calculating the average point of the points and assuming this point (centroid) as (0,0). Then, distance from centroid to the points is transformed to  $\sqrt{2}$  by calculating normalizing matrix to make  $\sqrt{2}$ .

#### 1.2.2 Creating Homography Matrix

In order to create homography matrix between two images, at least 4 points for each image has to be selected. If we call  $n$  as the number selected points for an image, we need to create  $2n \times 9$  matrix equations.

$$p_i = \begin{bmatrix} -x_i & -y_i & -1 & 0 & 0 & 0 & x_i x'_i & y_i x'_i & x'_i \\ 0 & 0 & 0 & -x_i & -y_i & -1 & x_i y'_i & y_i y'_i & y'_i \end{bmatrix}$$

Then it is possible to stack all points into the matrix and solve  $P\mathbf{H} = 0$  by SVD.

SVD  $P = USV^\top$  select the last singular vector of V as the solution to H.

Once we have  $H$  matrix, we can compute the projected coordinates of any point  $p(x,y)$

$$\begin{bmatrix} x'/\lambda \\ y'/\lambda \\ \lambda \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \text{such as:}$$

### 1.2.3 Denormalizing Points

Using normalizing transform matrixes calculated in [1.2.1](#) such that  $T_1$  and  $T_2$  for two images, calculated normalized homography matrix  $\hat{H}$  is denormalized using equation:

$$H = T_2^{-1} \hat{H} T_1$$

## 1.3 Image Warping

By using calculated homography matrices for each image pairs, images stayed on both left and right of the center images are warped. Firstly reference points of image are calculated using homography matrix  $H$  in order to learn new image shape after transformation. This is made by product of 4 corner points of the image and homography matrix [1.2.2](#).

After deciding new image shape, all points of the image are traversed, and multiplied with homography matrix to find new coordinates. These  $y$  and  $x$  offsets are also subtracted from new  $(y, x)$  coordinates of the image to fit image into new shape.

## 1.4 Blending and Interpolation

Not implemented. All warped images are projected sequentially into new image.

## 2 Experiments

All experiments are made using left-1, middle and right-1 images. Before doing experiments, common 12 points are selected using ginput. Later on, according to experiments' setup some of them used or some of them are changed randomly to create wrong matches. This is done for increasing speed in experiments.

## 2.1 Experiments with 5 points

### 2.1.1 5 Points Without Normalized Homography.



Figure 1: Panoramic image



Figure 2: Common points between left and middle image.



Figure 3: Common points between middle and right image.

### 2.1.2 5 Points With Normalized Homography



Figure 4: Panoramic image



Figure 5: Common points between left and middle image.



Figure 6: Common points between middle and right image.

### 2.1.3 5 Points with 3 Wrong Matches Without Normalized Homography.



Figure 7: Panoramic image



Figure 8: Common points between left and middle image.



Figure 9: Common points between middle and right image.

#### 2.1.4 5 Points with 3 Wrong Matches With Normalized Homography.



Figure 10: Panoramic image



Figure 11: Common points between left and middle image.



Figure 12: Common points between middle and right image.

### 2.1.5 5 Points with 5 Wrong Matches Without Normalized Homography.



Figure 13: Panoramic image



Figure 14: Common points between left and middle image.



### 2.1.6 5 Points with 5 Wrong Matches With Normalized Homography.

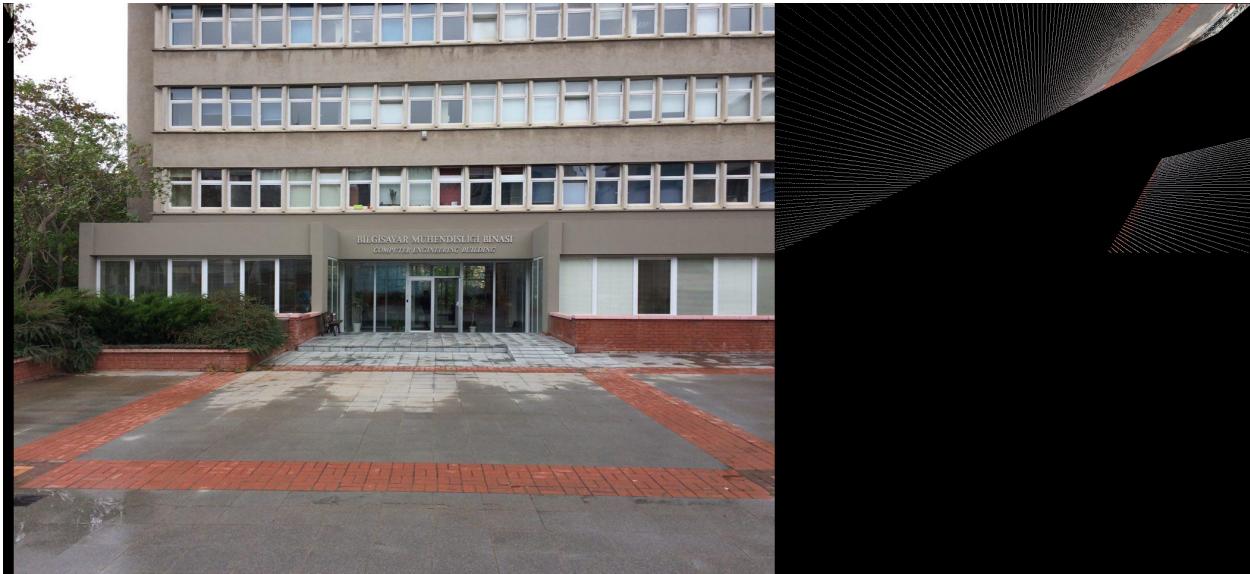


Figure 16: Panoramic image



Figure 17: Common points between left and middle image.



Figure 18: Common points between middle and right image.

## 2.2 Experiments with 12 points



Figure 19: Panoramic image



Figure 20: Common points between left and middle image.

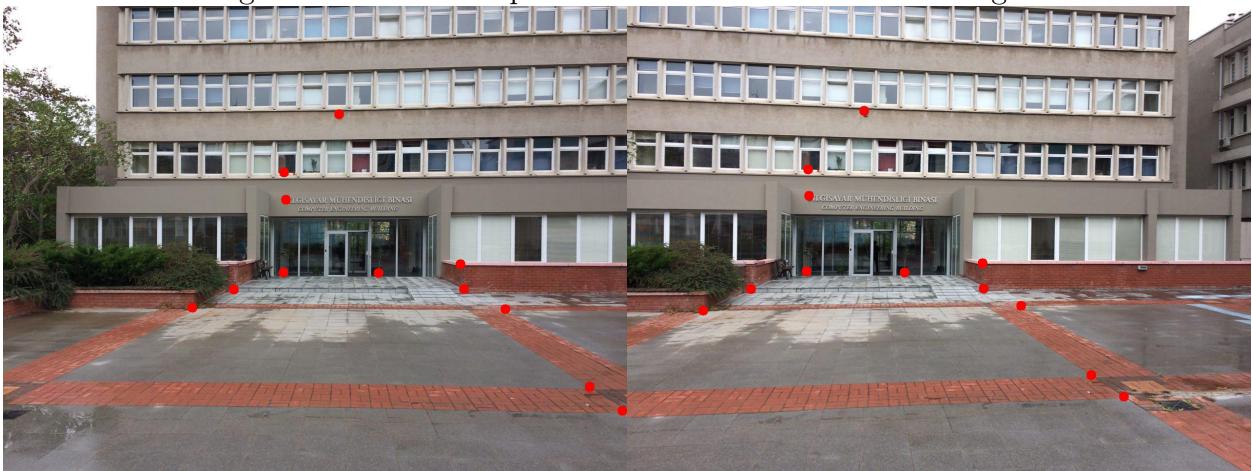


Figure 21: Common points between middle and right image.

### 2.2.1 12 Points With Normalized Homography



Figure 22: Panoramic image



Figure 23: Common points between left and middle image.

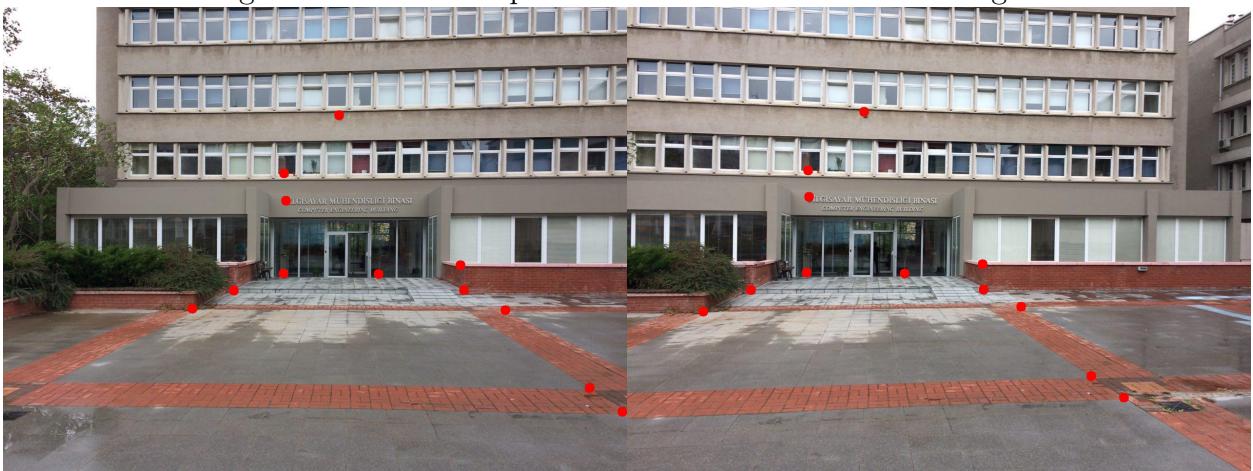


Figure 24: Common points between middle and right image.

## 2.2.2 12 Points with 3 Wrong Matches Without Normalized Homography.

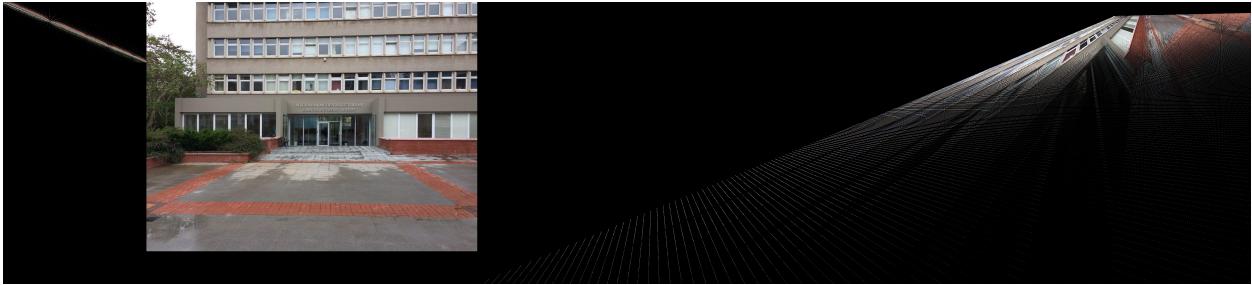


Figure 25: Panoramic image

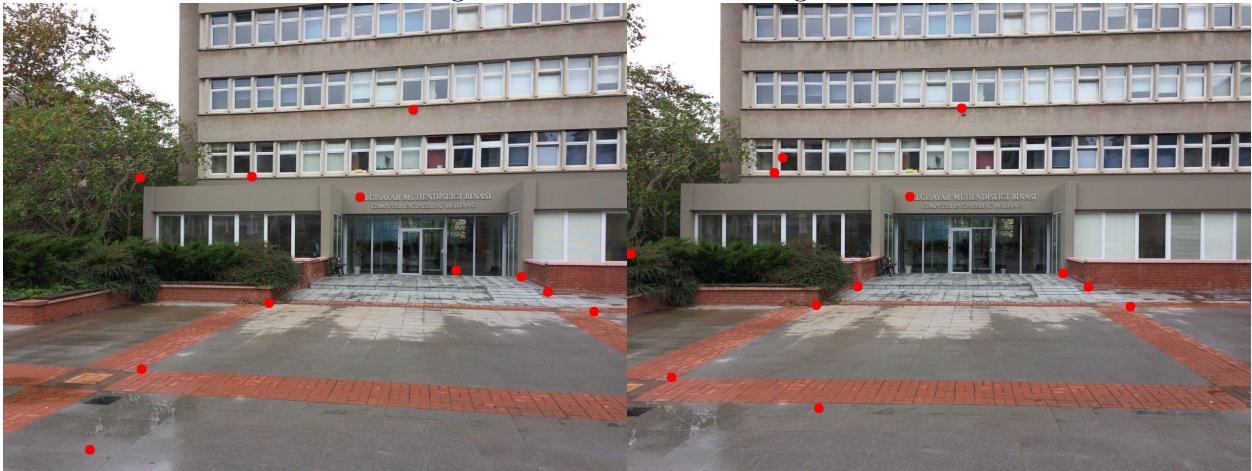


Figure 26: Common points between left and middle image.



Figure 27: Common points between middle and right image.

### 2.2.3 12 Points with 3 Wrong Matches With Normalized Homography.



Figure 28: Panoramic image

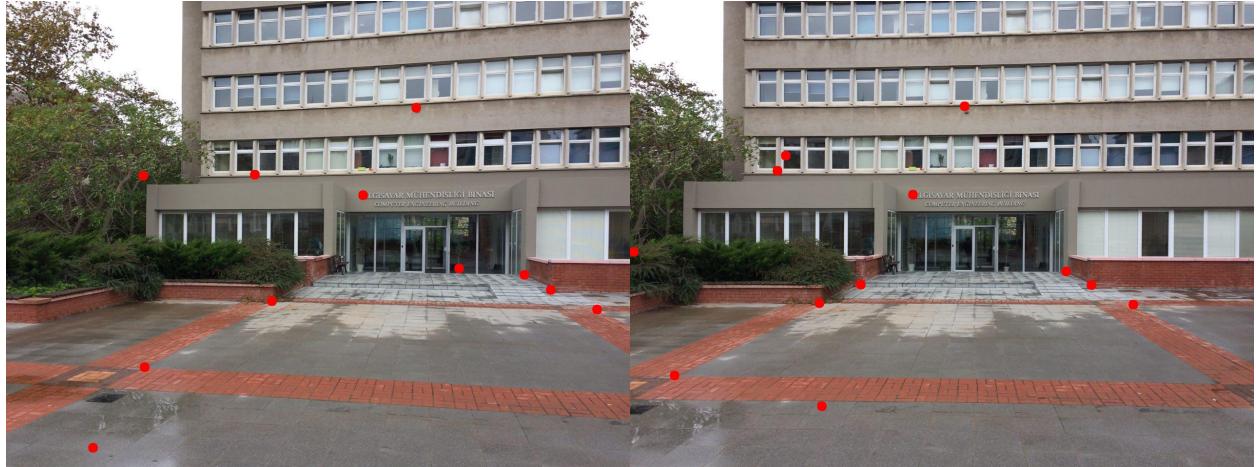


Figure 29: Common points between left and middle image.



Figure 30: Common points between middle and right image.

#### 2.2.4 12 Points with 5 Wrong Matches Without Normalized Homography.



Figure 31: Panoramic image

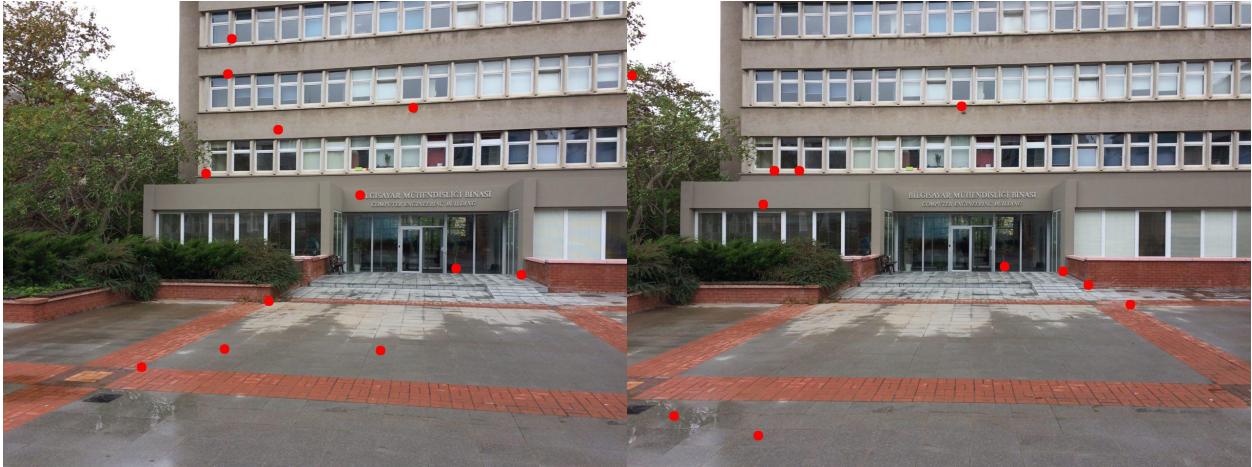


Figure 32: Common points between left and middle image.

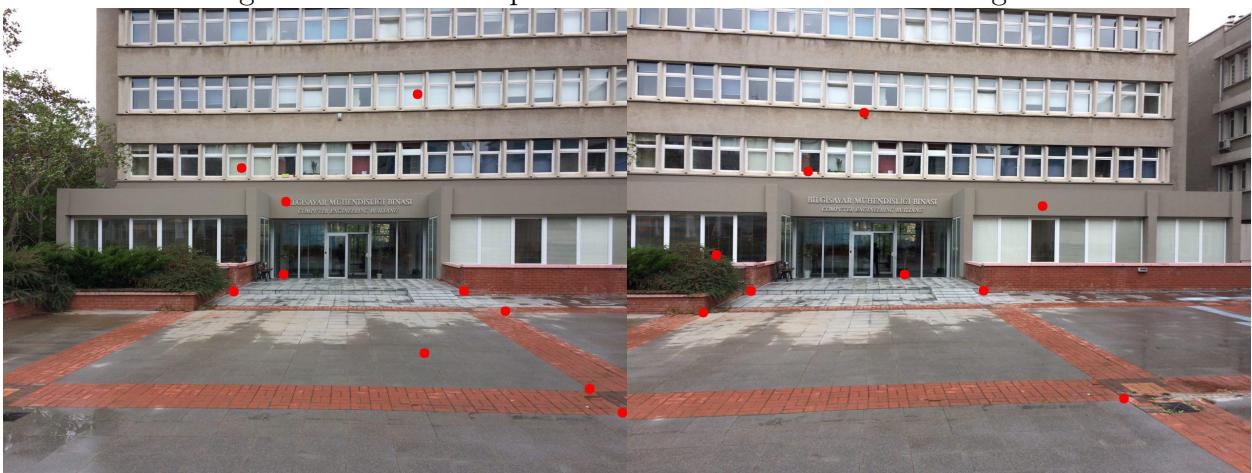


Figure 33: Common points between middle and right image.

### 2.2.5 12 Points with 5 Wrong Matches With Normalized Homography.

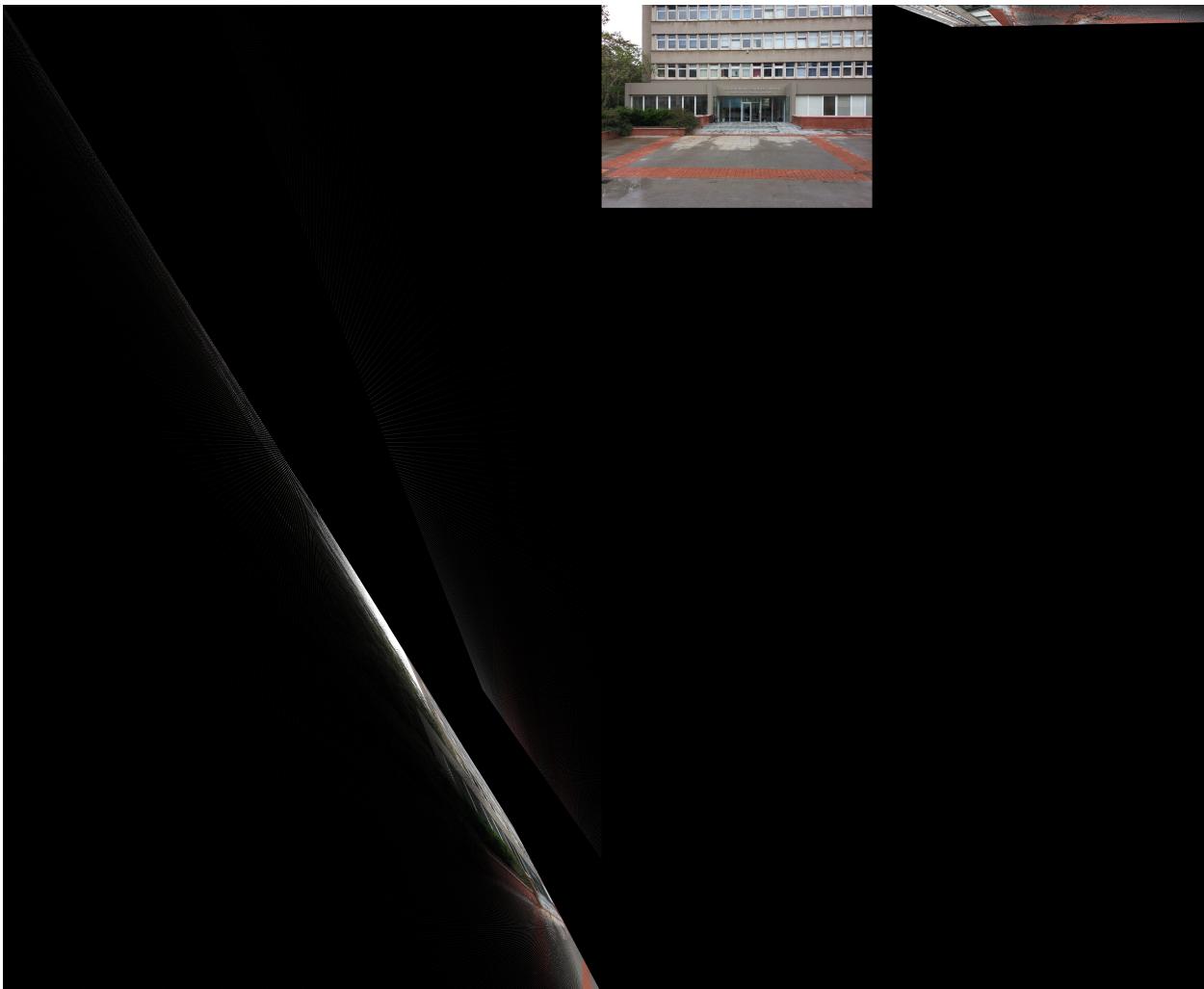


Figure 34: Panoramic image



Figure 35: Common points between left and middle image.

