IACV Homework 2021/2022

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Introduction

Main objective of the exercise was to perform appropriate processing of the given image in order to extract relevant information like specific features or geometrical aspects.

F1. Feature extraction

Performing efficient extraction of useful features requires to include a preprocessing step of the image. In this case a rather straightforward approach has been used as the original image was only converted into a grayscale image and then gaussian filtering was used in order to get rid of potential noise which could affect final results.

Figure 1. Preprocessed Image

In order to obtain edges it was decided to use canny filtering, however, canny filtering alone yielded results which weren't fully successful due to the lack of continuity of many lines, therefore dilation was used to enhance lines represented in the image.

Figure 2. Image after canny filtering

Particular lines were extracted with a use of Hough transform.

Figure 3. Extracted Lines

While corners where determined with a use of Harris Corner Detector and binarization of image with Otsu's algorithm.

Figure 4. Extracted Corners

G1. 2D reconstruction of a horizontal section

Stratified method has been used in order to rectify horizontal section of the building.

The first stage is based on performing an affine reconstruction. In order to do so it is necessary to find an image of a line in the infinity that is why multiple lines that are supposed to be parallel were chosen. Later on a rectifying homography projecting an image of line in the infinity into a line in infinity was constructed to obtain an affine rectification. Greater amount of used parallel lines should reduce influence of potential inaccuracy.

Figure 5. Calculation of an image of line in the infinity

Figure 6. Orthogonal lines constraints

In the next stage it was required to find at least two independent constraints to compute an image of conic dual to circular points. Unfortunately I wasn't able to find out a way to include information about position of the sun and vertical shadows casted on the building. This reason forced me to make a bit naïve assumption that red lines passing through corners of the 1st and 5th facade are orthogonal. Such a procedure allowed to proceed with following stages of the homework.

In the end 3 orthogonality constraints were used in order to obtain shape rectification.

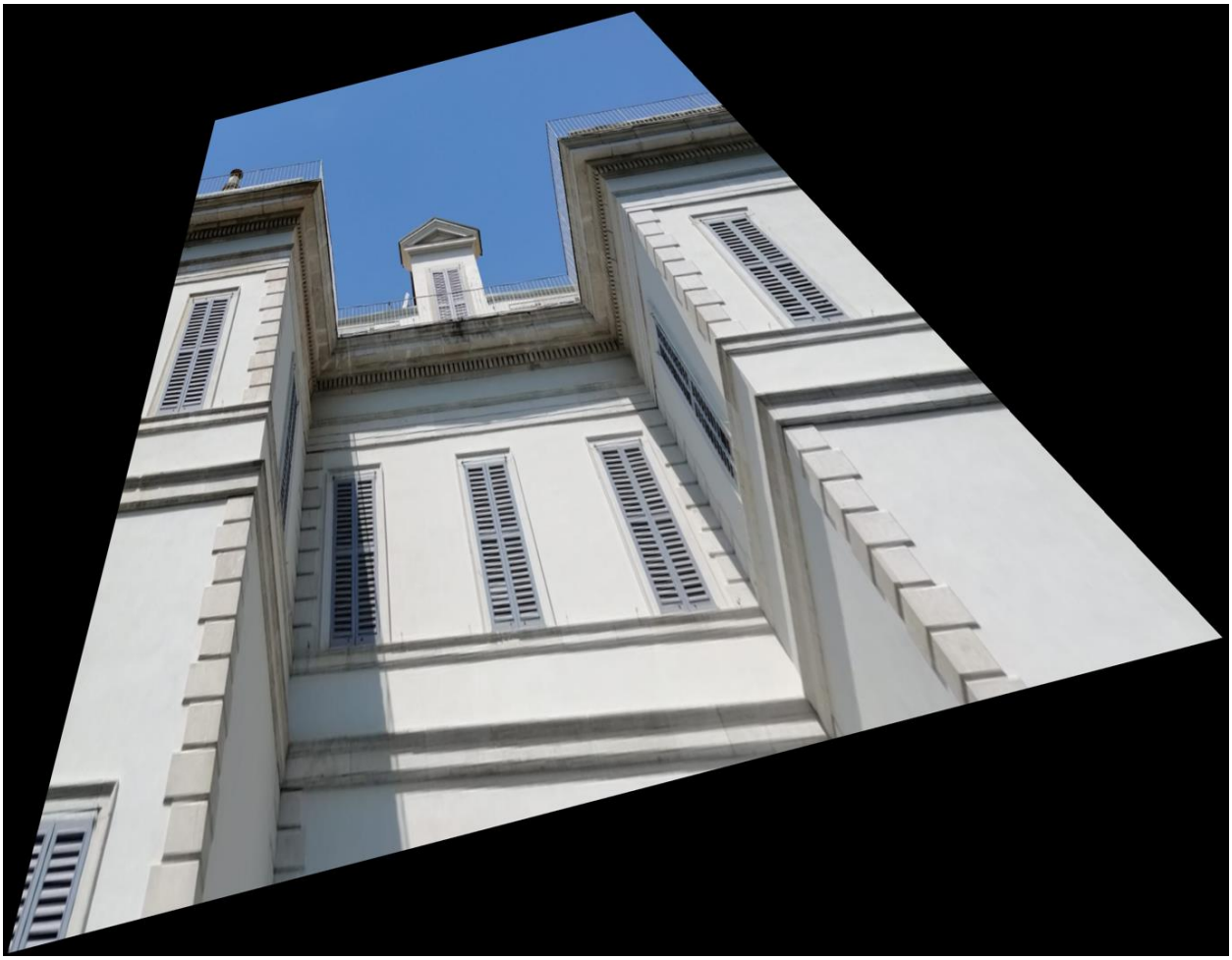

Figure 7. Shape rectification

Shape Rectification Homography

-1.32609251907600	0.344057571064256	0
0.344057571064256	-1.37305401538368	0
-6.67644431715553e-05	-0.000853688450753708	0.999999633379202

$$Ratio = \frac{\text{Facade 3}}{\text{Facade 2}} = 1.77$$

In the process of calculating the homography all the lines were normalized in order to reduce numerical errors.

G2. Calibration

In order to obtain calibration of a camera it was essential to determine an image of absolute conic. In order to do so, an already found image of line in the infinity and homography of shape reconstruction of horizontal plane were used. Additionally vanishing point v orthogonal to a horizontal plane needed to be determined. It was achieved simply by calculating an intersection of parallel vertical lines along the edges of windows on the facade number 3. It is worth noticing that first equation provides only 2 independent constraints as coordinates of lines in planar plane are homogeneous.

$$(1) \quad \boldsymbol{l}' \infty = \omega \mathbf{v}$$

$$(2) \quad h1^{\mathrm{T}} \omega h2 = 0$$

$$(3) \quad h1^{\mathrm{T}} \omega h1 - h2^{\mathrm{T}} \omega h2 = 0$$

Absolute Conic

2.04167721284724	0	-1228.77399663710
0	1	-519.657974811731
-1228.77399663710	-519.657974811731	2612690.98541901

Calibration matrix K was obtained by applying a Cholesky factorization on the matrix representing an absolute conic. Unfortunately due to unavoidable numerical errors and lack of accuracy this matrix wasn't always positive definite what is a required property in order to compute Cholesky factorization. A solution addressing this problem included usage of *nearestSPD* function which computes the nearest matrix (minimizing the Frobenius norm of the difference) that has the desired property of being SPD.

K

1367.48188362729	372.738640520254	0.717276860141125
0	1707.00447703292	0.339519099074483
0	0	1

f_x = 1367

f_y = 1707

Principal Point = (1, 0)

G3. Reconstruction of a vertical façade

Computation of rectified image of vertical facade required in the first place finding an image of conic dual to circular points. In order to find images of these circular points it was necessary to compute a line in the infinity but this time with respect to the frontal elevation of the building. Similarly as in the horizontal reconstruction at least 2 pairs of parallel lines were needed to do so.

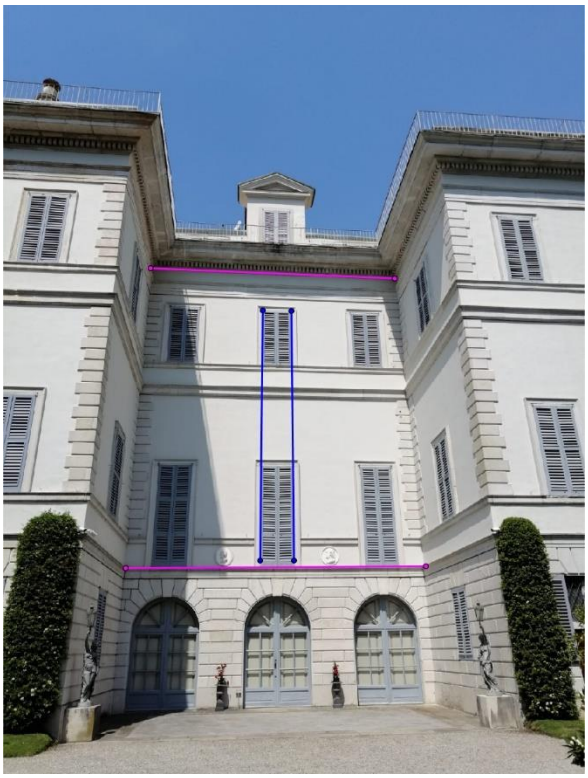

Figure 8. Calculation of an image of line in the infinity

It is known that images of circular points are located at the intersection of an image of absolute conic and line in the infinity therefore system of two equations presented below needed to be solved to obtain these circular points.

$$x^T \omega x = 0$$

$$l^T x = 0$$

In the very end SVD was performed to obtain reconstruction of vertical plane.

Figure 9. Reconstruction of vertical plane

Shape Rectification Homography

0.351956461839876	-0.936016252017220	0.000474266583526676
1.00668434644207	0.378528723003106	-5.09778809936514e-05
-0.000122554684524231	0.000460603772188371	0.999999886412251

G4. Localization

$$cameraWrtPlanarFace = (K^{-1}H)^{-1}$$

Camera With Respect To Planar Face

265.255567810574	1582.98333885541	-332.670029025091	333.109548174475
-913.302215482920	267.140259861405	565.012181903283	-565.388186883306
983274.428205102	153955.647402736	1516602.63176380	-1516109.73903341
0	0	0	1

The last column represents O which is a beginning of the coordinate system of the camera with respect to the planar face of vertical facade.