**NATIONAL UNIVERSITY OF SINGAPORE**

**EXAMINATION FOR**

(Semester II: 2017/2018)

**EE4212 – COMPUTER VISION**

April / May 2018 - Time Allowed: 2 Hours

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INSTRUCTIONS TO CANDIDATES:

1. This paper contains **FOUR (4)** questions and comprises **FIVE (5)** printed pages.
2. Answer all **FOUR (4)** questions.
3. This is a CLOSED BOOK examination but candidates are allowed to bring in **ONE (1)** A4 sheet of paper, on which they may write any information, into the examination hall.
4. Programmable calculators can be used in the examination.

**Q1**

a) Compute the left epipole of the Fundamental matrix $\boldsymbol{F}=\begin{bmatrix}0 & 0 & 0\\ 0 & 0 & -1\\ 0 & 1 & 0\end{bmatrix}$ and thus describe the configuration of the epipolar lines on the left image. Explain clearly your step in obtaining the epipole and your subsequent reasoning for marks to be awarded.

(7 marks)

b) You are using the celebrated 8-point algorithm to solve the epipolar geometry, because the solution can be easily obtained by solving a simple linear least squares system of the form $\boldsymbol{Ax}=\mathbf{0}$. From theoretical consideration of the solution space of such a homogeneous system of equations, you know that even you have $n$>8 correspondences, the rank of **A** should be eight. However, in practice, there might be circumstances under which you obtain (i) rank (**A**) = 9 (where the 9$^{th}$ singular value of **A** is quite large, so it cannot be attributed to image noise), (ii) rank (**A**) < 8. Explain how these circumstances might arise.

(6 marks)

c) Explain clearly whether or not each of the following scenarios could impact on the quality of the disparity estimates obtained from a stereo pair of cameras arranged in the simple parallel configuration (with their optical axes perpendicular to the baseline): (i) when the scene in view consists of urban buildings with highly repetitive pattern; (ii) when the displacement between the two stereo cameras is large; (iii) when the scene in view contains moving objects like car (assuming no motion blur). Note that in (ii), you are asked to comment on the quality (not the quantity) of the disparity estimates, nor are you asked to comment about the quality of the depth estimates

(6 marks)

d) (i) Do you think the value of the Fundamental matrix $\boldsymbol{F}$ depends on the choice of the world coordinate frame? (ii) Do you think it is true to say that any 3×3 matrix of rank 2 corresponds to the essential matrix of some stereo pair of cameras? Explain your choices.

(6 marks)

**Q2.**

a) (i) Referring to Fig. Q2a, compute the optical flow ($v_x$,$v_y$) at the centroid of the square, given the two normal flow measurements $v_{n1}$ and $v_{n2}$ on two of the sides, assuming that the whole square is moving with the same image velocity. Show your working clearly; otherwise no marks will be awarded. (ii) Can this assumption that the image velocity in the square is spatially uniform be strictly true if the square is moving towards us in 3D?

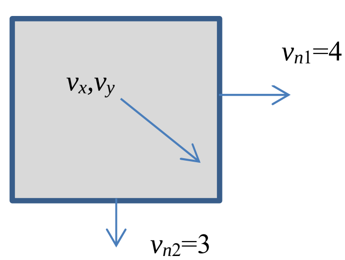



**Fig. Q2a.** Image of a square moving with optical flow ($v_x$,$v_y$)

(5 marks)

b) Suppose you want to estimate optical flow of a scene under rainy conditions. The image of the scene $I$ is now a superimposition of that of the clear scene ${}^{clear}I$ and that due to rain streaks ${}^{rain}I$ (see the left figure in Fig. Q2b), i.e.,

$$I = {}^{clear}I + {}^{rain}I$$

Discuss two possible problems with using Brightness Constancy Constraint (BCC) in this rainy scenario to obtain the optical flow of the background scene. (Hint: discuss problems arising from rain only, and pay attention to the four image patches in Fig. Q2b for the two problems).

(8 marks)

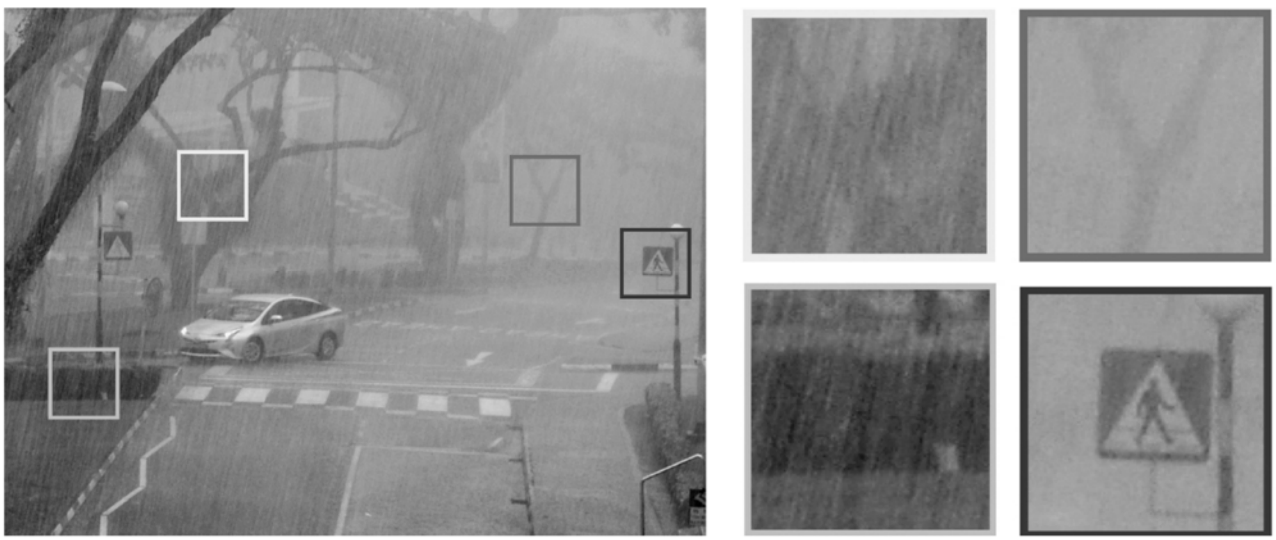


**Fig. Q2b.** Rainy scene (left), and details of four image patches (right)

c) Suppose you can assume that rain streaks are always grey in color, i.e. the intensity of the rain streaks are equal in each of the RGB channels, ${}^{rain}_{R}I = {}^{rain}_{G}I = {}^{rain}_{B}I$. It strikes on you that instead of using the grey level intensity $I$ in the optical flow objective function, you can define the residue image $I'$ as follows ${}_{R}I - {}_{G}I$ and use this residue image in the optical flow objective function. Explain the advantages and disadvantages of this scheme to estimate the optical flow of the background under rainy scenarios.

(8 marks)

d) You believe that image gradients, as opposed to brightness, are more robust against ambient illumination changes, i.e., image gradients are conserved under both camera motion <u>and</u> ambient illumination change, unlike image brightness. This belief that image gradients remain constant can be termed the gradient constancy constraint (GCC). Explain the advantages and disadvantages of this GCC constraint in estimating the optical flow of the background for rainy scenes with possibility of lightning.

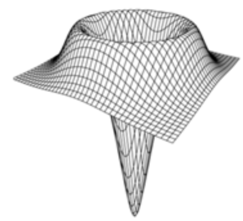
(4 marks)

# Q3

a) Given a space point at distance $d$ from a perfect lens with focal length $f$, how far should we place the image plane from the lens in order to have the imaged scene point in perfect focus? Explain the concept of the depth of field, and how is it related to the aperture.

(6 marks)

b) In the early stages of many computer vision systems, the isotropic filter shown on the right is often applied to an image $I(x, y)$ in the following way: $[\nabla^2 G_\sigma(x, y)] * I(x, y)$. What is the purpose of this filter? How would the results differ if instead this operation: $G_\sigma(x, y) * \nabla^2 I(x, y)$ were performed? And alternatively if this operation: $\nabla^2[G_\sigma(x, y) * I(x, y)]$ were performed?



(6 marks)

c) Consider the following two kinds of filter kernels, A and B:

A

| | | | | | |
|---|---|---|---|---|---|
| 0 | -1 | -1 | -1 | -1 | 0 |
| -1 | -2 | -3 | -3 | -2 | -1 |
| -1 | -3 | 12 | 12 | -3 | -1 |
| -1 | -3 | 12 | 12 | -3 | -1 |
| -1 | -2 | -3 | -3 | -2 | -1 |
| 0 | -1 | -1 | -1 | -1 | 0 |

B

| | | | | | |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 |
| -1 | -2 | -3 | -3 | -2 | -1 |
| -1 | -3 | -4 | -4 | -3 | -1 |
| 1 | 3 | 4 | 4 | 3 | 1 |
| 1 | 2 | 3 | 3 | 2 | 1 |
| -1 | -1 | -1 | -1 | -1 | -1 |

Given that the sum of all taps in each filter kernel is zero, how will each filter respond to an image region having only uniform brightness? Which filter is better described as an oriented edge detector? What orientation of edges is it best able to detect?

(4 marks)

d) Efros and Leung's algorithm for texture synthesis (pixel by pixel) is a data driven algorithm. It is very effective but is known to be very slow. Later an improved algorithm was developed. Explain what solutions are proposed to speed up the Efros and Leung's original algorithm.

(4 marks)

**Q4**

a) Given a 2x2 image shown below. The pixel values are given by P1 = (0,0,1), P2=(1,0,0), P3=(2,1,0) and P4=(0,1,2). Apply k-means to segment this small image into two parts.

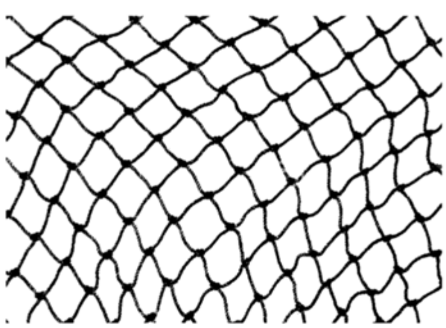
| | |
|---|---|
| P1 | P2 |
| P3 | P4 |

(5 marks)

b) Describe the process of extracting the SIFT feature from an image patch.

(10 marks)

c) Describe the steps you would use to determine the locations of the knots (crossing points) in a fishing net within images like the ones shown below. How would you cope with the fact that you could be far or close to the net when the image is recorded? Start at the pre-processing stage.



(15 marks)

**END OF PAPER**