Midterm #1

October 9, 2018

Weight: 15% of final mark (150 points)

Time allotted: 90 minutes

ID number: ________________ **Name:** ______________________________

Instructions PRIOR to beginning the exam

a) Please **DO NOT** start the exam or flip the pages until instructed to do so.

b) Write your name and ID number in the spaces provided at the top of this page

c) Please place your **student identification card** on the desk for verification.

d) **No electronic aids** (phones / calculators / laptops / tablets / etc.) are allowed.

e) This is a closed book exam. **One single page of handwritten notes is allowed**. Notes collected at the end.

Instructions DURING the exam

a) Carefully read all instructions.

b) Observe the relative value of each question and **budget your time** accordingly.

c) Answer questions neatly in the space provided. You may do the questions in any order.

d) The back page of your exam is blank. Feel free to use it as scrap paper if you wish.

e) When finished, please hand in your entire exam paper to your instructor.

Grade Table (for teachers use only)

Question	Points	Score
1-10	50	
11	10	
12	10	
13	10	
14	10	
15	10	
16	10	
17	10	
18	10	
19	20	
TOTAL	**150**	

Part 1 multiple choice questions: 50 points, 5 points each

NOTE: One, none or multiple choices could be true. Circle the answers that are correct.

1. Consider the pinhole camera model. Circle the statements that are true in the case when the pinhole is too large.
   a. you get blurring artefacts on the image plane
   b. many rays passing through one object point hit the image plane
   c. diffraction effects blur the image
   d. the image is lighter than if the pinhole is smaller

2. Thin lens properties. Circle the ones that are true.
   a. An incident ray traveling through the focal point is not refracted and continues in the same direction
   b. An incident ray traveling parallel with the optical axis will refract and travel through the focal point on the other side of the lens
   c. All rays emanating from an object point in focus will converge on the same point on the image plane

3. A high pass filter
   a. Can be computed by cutting low frequencies in the Fourier spectrum
   b. Can be computed by cutting high frequencies in the Fourier spectrum
   c. Will blur image details
   d. Will sharpen image details
   e. Can be computed as the difference between impulse filter and a low pass filter
   f. Can be computed as taking the inverse of the low pass filter matrix

4. Edge detection in a noisy image. Circle all true statements
   a. Noise will cause high image gradients in uniform areas of the image
   b. Noise will cause high gradients at edge locations
   c. To alleviate noisy gradients, we can first convolve the image with a high pass filter then extract derivatives
   d. To alleviate noisy gradients, we can use the LoG (Laplacian of Gaussian) filter instead of derivative filters

5. Properties of a 2D Gaussian filter $G\sigma = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right)$. Circle all that are correct.
   a. Is a low pass filter
   b. A Gaussian convolved with a Gaussian is a high pass filter
   c. Is separable into a product of a column and a row 1D filters
   d. For a filter of the same size, the larger the sigma σ, the more blur we get after filtering
   e. For the same sigma, the larger the filter, the more blur we get after filtering

depends on the size of kernel

gauss(K_1, σ) will blur less than gauss(K_2, σ)

$K_1 < K_2$ and $\sigma > \frac{K_1}{6}$

6. The autocorrelation function used in the Harris corner detector has the following form

$E(u,v) = \sum_{x,y \in W(u,v)} (I(x+u, y+v) - I(x,y))^2$, where $W(u,v)$ is a small window around the location (u,v). Circle all properties that are true

a. The autocorrelation function for a point in a uniform region is constant
b. The autocorrelation function for a corner is constant
c. The autocorrelation function for a point on an edge has high values along the edge direction
d. The autocorrelation function for a corner will have a minimum at the corner location

7. Circle all correct statements. RANSAC is a technique

a. Used in model fitting to deal with large input data
b. Used in model fitting to deal with outliers in the input data
c. That repeatedly fits the model to a random selection of minimum number of data points needed to fit the model
d. That can be used for robustly computing the homography between two images given a set of corresponding points
e. That can be used for robustly computing the a set of corresponding points between two images

8. Harris corners are invariant to

a. Image translation
b. Image rotation
c. Affine transformations
d. Scaling
e. Intensity variation

9. Properties of 2D affine transformations. Circle what is true in the most general case.

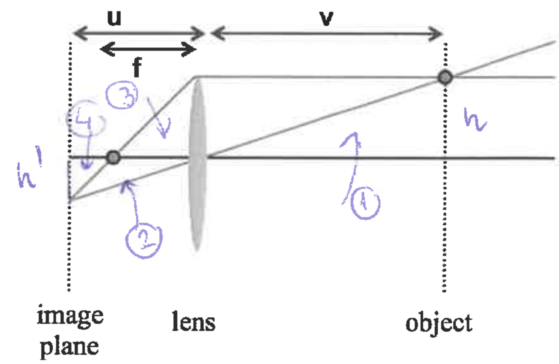
a. it is linear
b. parallel lines remain parallel
c. a square is transformed to a rectangle
d. ratios are preserved
e. has 4 degrees of freedom

10. Properties of 2D projective transformations (homographies). Circle what is true in the most general case.

a. it is linear
b. parallel lines remain parallel
c. a square is transformed to a rectangle
d. ratios are preserved
e. has 9 degrees of freedom

Part 2 understanding concepts: 80 points, 10 points each

11. Thin lens equation. Relate to the drawing on the right for notations. Derive the thin lens equation that relates the focal length *f* with the distance from the object point to the lens *v* and the distance from the lens to the image plane *u*.



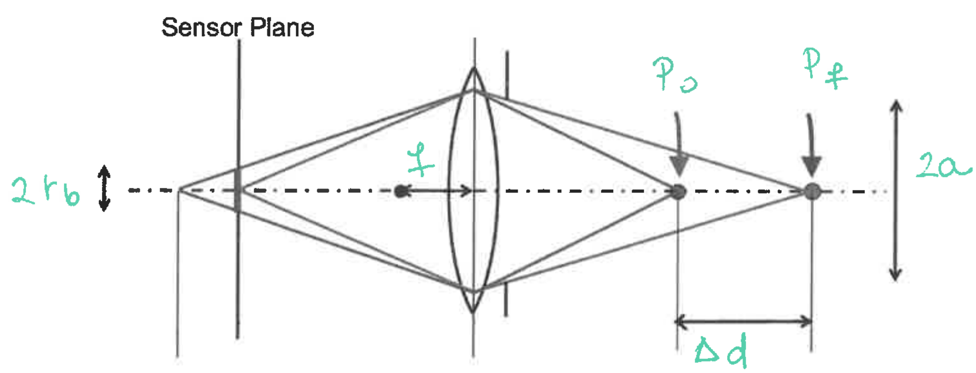
Triangles ① and ② $\frac{h'}{h} = \frac{u}{v}$

Triangles ③ and ④ $\frac{h'}{h} = \frac{u-f}{f}$

$$\Rightarrow \frac{u}{v} = \frac{u-f}{f}$$

$$\frac{u}{v} = \frac{u}{f} - 1 \,\Big|\, :u \Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u} \Rightarrow \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

12. Thin lens camera model.
   a. (6p) Consider the drawing below that schematically represents a thin lens camera. Clearly mark on the figure the following elements
      (a) **f** = Focal length
      (b) **a** = aperture
      (c) $\mathbf{r_b}$ = blur circle on the image plane
      (d) $\mathbf{\Delta d}$ = depth of focus
      (e) **Pf** = point in focus
      (f) **Po** = point out of focus



b. (4p) Give the two photographs below. Circle the correct answers that explain the relationship between the depth of field, the focal length, and the aperture.

aperture: large / small
depth of field: large / small
focal length: large / small

aperture: large / small
depth of field: large / small
focal length: large / small

13. Consider the following 1D image I=[1 2 3 0 2 3 4] and the box filter f = [1 1 1].

a. (6p) Construct the image J that is the result of the convolution of I with f. Use padding if necessary.

pad [0 1 2 3 0 2 3 4 0] * [1 1 1]

J = [3 6 5 5 5 9 7]

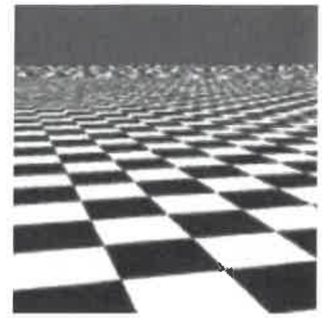
b. (2p) What kind of filter is the box filter ?

low pass filter

c. (2p) What happens with the image as a result of such a filtering operation ?

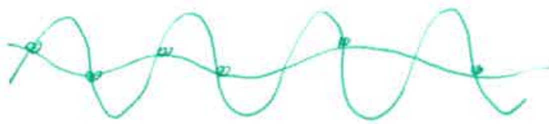
image is blurred, but might have some edgy artifacts

14. Image down-sampling and aliasing. Look at the picture. It is a good example of aliasing during subsampling.



a. (5p) Explain what is *aliasing*. Make a drawing of a 1D signal that explains your definition.

aliasing – noise introduced by subsampling



b. (5p) How can you down-sample an image to reduce aliasing?

Convolve image with a Gaussian then subsample.

→ Gaussian pyramid.

15. Image gradient. $\nabla I = (I_x, I_y)$

a. (3p) Write down a filter that will compute the gradient in the x-direction I_x

$$g_x = \begin{bmatrix} -1 & 1 \end{bmatrix} \quad \text{or} \quad \begin{bmatrix} 0 & 0 & 0 \\ -1 & 2 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

b. (3p) Write down a filter that will compute the gradient in the y-direction I_y

$$g_y = \begin{bmatrix} 1 \\ -1 \end{bmatrix} \quad \text{or} \quad \begin{bmatrix} 0 & -1 & 0 \\ 0 & 2 & 0 \\ 0 & -1 & 0 \end{bmatrix}$$

c. (4p) Explain how can you use the image gradient to compute edges in an image

edge = high magnitude of image gradient

$$\nabla I = [I_x \; I_y]$$

$$|\nabla I| = \sqrt{I_x^2 + I_y^2}$$

edge if $|\nabla I| > Th.$

16. Consider the filters and the images below. The images are filtered version of the "Lena" image with the filters.

original I_1 I_2 I_3 I_4 I_5

```
[[0.98 0.99 1.   0.99 0.98]
 [0.99 1.01 1.02 1.01 0.99]
 [1.   1.02 1.02 1.02 1.  ]
 [0.99 1.01 1.02 1.01 0.99]
 [0.98 0.99 1.   0.99 0.98]]/25
```

k_1 Gaussian more blur

```
[[0.1  0.39 0.59 0.39 0.1 ]
 [0.39 1.56 2.34 1.56 0.39]
 [0.59 2.34 3.52 2.34 0.59]
 [0.39 1.56 2.34 1.56 0.39]
 [0.1  0.39 0.59 0.39 0.1 ]]/25
```

k_2 Gaussian less blur.

```
[[0 0 0]
 [0 1 0]
 [0 0 0]]
```

k_3 identity

```
[[-1  0  1]
 [-2  0  2]
 [-1  0  1]]
```

k_4 Sobel x

```
[[ 1  2  1]
 [ 0  0  0]
 [-1 -2 -1]]
```

k_5 Sobel y

a. (5p) Match filters with images.

I_1 – K1 I_3 – K5 I_5 – K 3

I_2 – K2 I_4 – K4

b. (5p) Group the filters into the 3 categories. Write the number of the filter in its category.

(a) low pass: K1 , K2

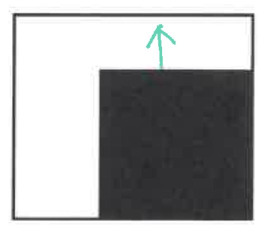
(b) high pass: K4 , K5

(c) neither low-pass nor high-pass: K3

17. Harris corner detector. Consider the image below.

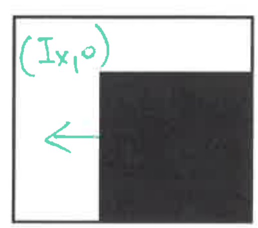
a. (3p) Draw the gradient vector ∇I at one location along the horizontal edge. What is the value of ∇I along the horizontal edge ? Which component is 0?

$(0, I_y)$



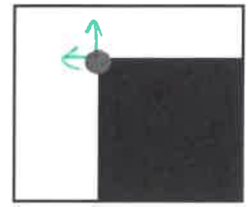
$\nabla I=(I_x,I_y)=$ $(0, I_y)$

b. (3p) Draw the gradient vector ∇I at one location along the vertical edge. What is the value of ∇I along the vertical edge. Which component is 0?



$\nabla I=(I_x,I_y)=$ $(I_x, 0)$

c. (4p) What are the values of the 4 components of the matrix M for the corner in this situation. Think what is the dot product between two perpendicular vectors and the form of the gradients you have determined at points a,b.



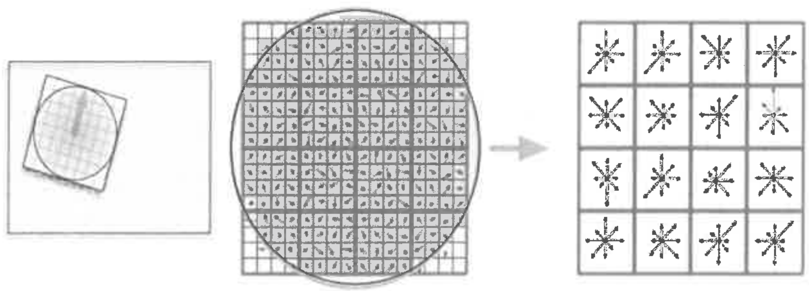
$$M = \begin{bmatrix} \sum I_x^2 & \sum I_x I_y \\ \sum I_x I_y & \sum I_y^2 \end{bmatrix} = \begin{pmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{pmatrix}$$

gradient direction aligns with x or y axis.

λ_1, λ_2 large to detect corner

Hint: Think which components are 0.

18. Consider the SIFT detector and descriptor.



a. (4p) What is stored in the 128 - dimensional descriptor?

128 — 8 X (4x4) histogram of oriented gradients.

8 orientations in the histog. each sub-region. 4 X 4 subregions.

b. (3p) What aspects of the SIFT descriptor design promote robustness to lighting changes?

the fact that is using gradient orientations in the descriptors. Gradients are invariant to intensity variations. (robust)

c. (3p) What aspects of the SIFT descriptor design promote robustness to rotation and translation?

rotation: a main orientation is detected (from histogram) and the patch is rotated to a standard orientation before computing the descriptor.

translation: gradient values do not depend on location. (filters are invariant to translations)

Part 3 using your computer vision knowledge: 20 points

Design a computer vision system that will create a panorama from the two images above.

a. (10p) Identify all steps in your process and the best technique for each step (among the ones discussed in class).

b. (10p) In particular, indicate how to deal with the problems below. Indicate the steps from your method that deal with/solve these problems. You can have more than one step to take care of a problem. For example noise could be a problem for few of your steps.

(a) noise in the images
(b) scale difference
(c) light variation
(d) repetitive structures
(e) images are taken from the same viewpoint.

a. (1.) feature detection and descriptors
SIFT

(2) feature matching with ratio distance as metric

(3) calculate motion model - homography
DLT + RANSAC

(4) warp and stitch panorama

b. (a) SIFT using gaussian pyramid that involves smoothing w. Gaussian filter
can run an additional filtering if different noise
RANSAC - takes care of bad matches due to noise

(b) (c) SIFT accounts for illumination variation as it uses gradients, also scale variation using gaussian pyramid.

(d) ratio distance in step (2)

(e) homography correct for same viewpoint.