Written Examination

2014-02-04

Name: _____ First Name: _____

Program of Study: _____

Matr.-No.: _____ Exam #: _____

Information:

- Write your name and matriculation number on **every sheet of paper**.
- Answer each question on the provided sheet. If more space is needed, **use a new sheet of paper for each question**.
- If you have to draw to answer a question, multiple templates are provided. **Cross out wrong answers!**
- At the end of the examination this cover sheet together with the question sheets and al additionally used paper has to be returned.
- Duration of the exam: **60 minutes**.
- **No additional aids** (notes, calculator, ...) are allowed.
- Use a pen with **blue or black ink** for writing down your solutions. Text written with pencils or red/green pens will not be graded.

With my signature I confirm that I have **read and understood** the information above.

_____

Signature

Question:	1	2	3	4	5	Total
Points:	13	16	12	15	13	69
Score:						

Exam Number
#

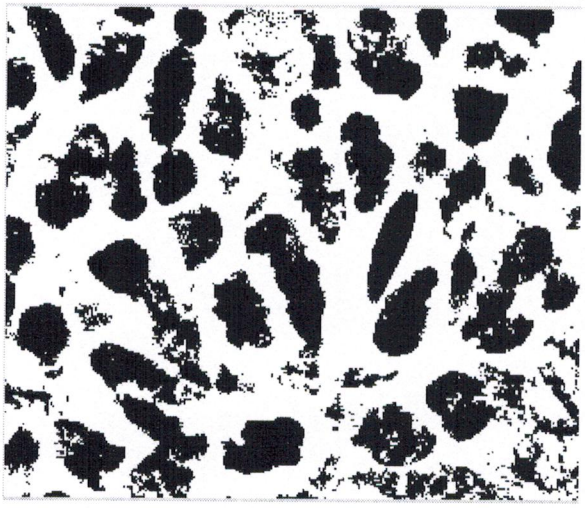
Question 1 ..... $(\Sigma = 13)$

(a) What is thresholding? **(2 pts)**

(b) Name two use-cases of thresholding. **(2 pts)**

(c) Describe Otsu's thresholding method. **(4 pts)**

(d) You have used a thresholding algorithm and obtained the following image:



i. We want to clean up the image using morphological operators. Explain how the morphological operators work. **(3 pts)**

ii. Which operator(s) would you use on this image and why? Remember: Foreground are the black cells. **(2 pts)**

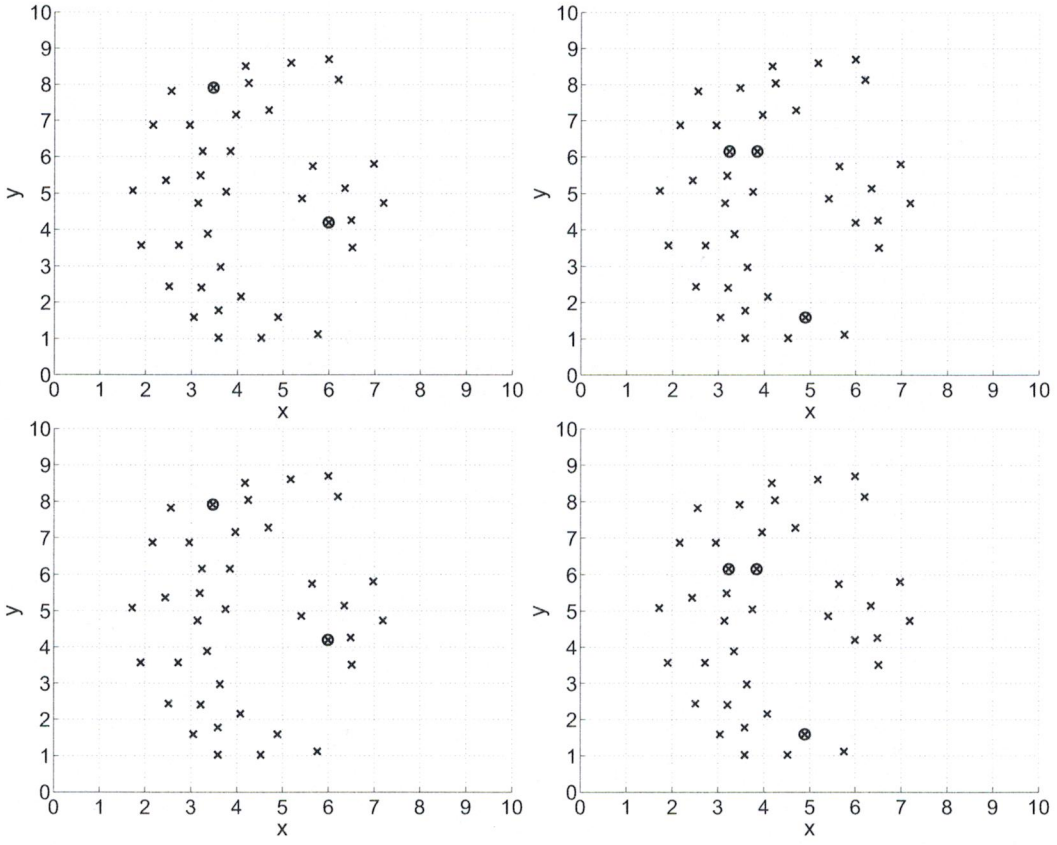
Question 2 ..... $(\Sigma = 16)$

(a) List the steps of the k-Means algorithm. **(4 pts)**

(b) Properties of k-Means **(3 pts)**

Will k-Means always converge?	◯ Yes	◯ No
Does k-Means always find the best solution with respect to its objective function?	◯ Yes	◯ No
Is the problem of finding the optimal solution NP-complete?	◯ Yes	◯ No

(c) Sketch the (approximate) cluster boundaries and their means k-Means would give for the following dataset for $k = 2$ (left) and $k = 3$ (right). The circled points are the initial means. **(4 pts)**



(d) List 1 advantage and 2 disadvantages of k-Means. **(3 pts)**

(e) Briefly describe how k-Means can be used for image segmentation. **(2 pts)**

Question 3 ..... $(\Sigma = 12)$

(a) Please fill in the following Matlab code fragment to complete the Hessian detector. **(4 pts)** (Pseudo-code is sufficient, as long it is unambiguously clear what is meant.)

```
function [px, py] = computeHessian(filename, sigma, thresh)
    % ------------------------------------------------------------
    % Preprocessing
    % ------------------------------------------------------------
    I               = loadImage(filename);
    Ig              = gaussianfilter(I, sigma); % Gaussian filter
    [Ix, Iy]        = gaussderiv(I, sigma);     % first derivatives
    [Ixx, Ixy, Iyy] = gaussderiv2(I, sigma);    % second derivatives

    % ------------------------------------------------------------
    % Compute Hessian score for each pixel
    % ------------------------------------------------------------
    [height, width] = size(I);
    score = zeros(height, width);
    for y = 1:height
        for x = 1:width
            % Compute Hessian score for pixel I(y, x) and store it in
              score(y, x)
```

```
        end
    end

    % ------------------------------------------------------------
    % Postprocessing
    % ------------------------------------------------------------
    % Extract the interest points from the computed score map.
    [py, px] = find(score > thresh)
end
```

(b) The above code is still not fully correct. What is the error and how can it be fixed? **(2 pts)** (A verbal explanation is sufficient).

(c) Details to the Hessian detector.

i. What image structures does the Hessian detector react to? **(2 pts)**

ii. Properties of Hessian keypoints **(2 pts)**

Is the Hessian detector scale-invariant? ◯ Yes ◯ No

Is the Hessian detector rotation-invariant? ◯ Yes ◯ No

iii. List 3 different computer vision tasks for which Hessian interest points can be used. **(2 pts)**

Question 4 ..... **($\Sigma = 15$)**

(a) Adaboost

i. Briefly explain the steps of the Adaboost *training* algorithm. **(3 pts)**

ii. What is the input and what is the output of this algorithm? **(2 pts)**

(b) Which property has to be fulfilled by the weak classifiers? **(1 pt)**

(c) How is a test point classified? Give the equation. **(2 pts)**

(d) What are the weak classifiers that are used for Viola-Jones face detection? (You may sketch to support your answer.) **(2 pts)**

(e) Integral Images

i. What is an integral image? **(1 pt)**

ii. Why and how are integral images used for Viola-Jones face detection? (You may sketch to support your answer.) **(2 pts)**

(f) Briefly explain how cascading classifiers for detection works. **(2 pts)**

Question 5 ..... $(\Sigma = 13)$

(a) Briefly explain the following concepts

i. Essential Matrix **(1 pt)**

ii. Epipolar constraint **(1 pt)**

(b) Eight-point algorithm **(4 pts)**

i. Fill in the first row of the following matrix in order to complete the Eight-point algorithm. Assume that the point correspondence is called $(\mathbf{a}, \mathbf{b})$ where $\mathbf{a} = (a_1, a_2)$ is located in the left image and $\mathbf{b} = (b_1, b_2)$ in the right image. (Hint: Use the derivation of the algorithm).

$$\begin{bmatrix} \square & \square & \square & \square & \square & \square & \square & \square & \square \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \end{bmatrix} \cdot \begin{bmatrix} F_{11} \\ F_{12} \\ F_{13} \\ F_{21} \\ F_{22} \\ F_{23} \\ F_{31} \\ F_{32} \\ F_{33} \end{bmatrix} = 0$$

ii. How do we solve this equation? (Use more than a single word!) **(1 pt)**

iii. Some problems might occur depending on the conditioning of the matrix. How can these be avoided by modifying the data? **(1 pt)**

iv. What can happen if one correspondence is incorrect? **(1 pt)**

(c) Rank constraints of the Fundamental Matrix.

i. Justify why we know that the Fundamental Matrix has rank 2. **(2 pts)**

ii. What would happen if F had full rank? **(1 pt)**

iii. How can we enforce the rank-2 constraint during Fundamental Matrix estimation? **(1 pt)**