Name: Matr.-No.:

Question 1 .... $(\Sigma = 10)$

Image Filtering

(a) How is convolution $G = H * F$ defined? What is it used for? **(2 pts)**

(b) State if the following properties of **correlation filtering** $(F \otimes H)$ are always valid. **(1 pt)**

i. $(a \cdot H + J) \otimes F = a \cdot H \otimes F + J \otimes F$

i. ____________

ii. $F[i,j] \otimes H[i,j] = F[i,j] * H[-i,-j]$

ii. ____________

(c) What problems do occur at the border of the image when performing filtering? How can these be avoided besides zero-padding? Describe two methods and name one advantage and one disadvantage for each of them. **(2 pts)**

(d) Image filtering and the Fourier transform **(2 pts)**

i. The Fourier transform of a Gaussian is also a Gaussian.

i. ____________

ii. The Fourier transform of a box filter is also a box filter.

ii. ____________

iii. The Gaussian filter emphasizes the low frequencies.

iii. ____________

iv. Truncating the Fourier spectrum at a given frequency below the maximum frequency and only keeping the lower frequencies causes aliasing artifacts in the image.

iv. ____________

(e) What is a Gaussian Pyramid and how is it created? **(1 pt)**

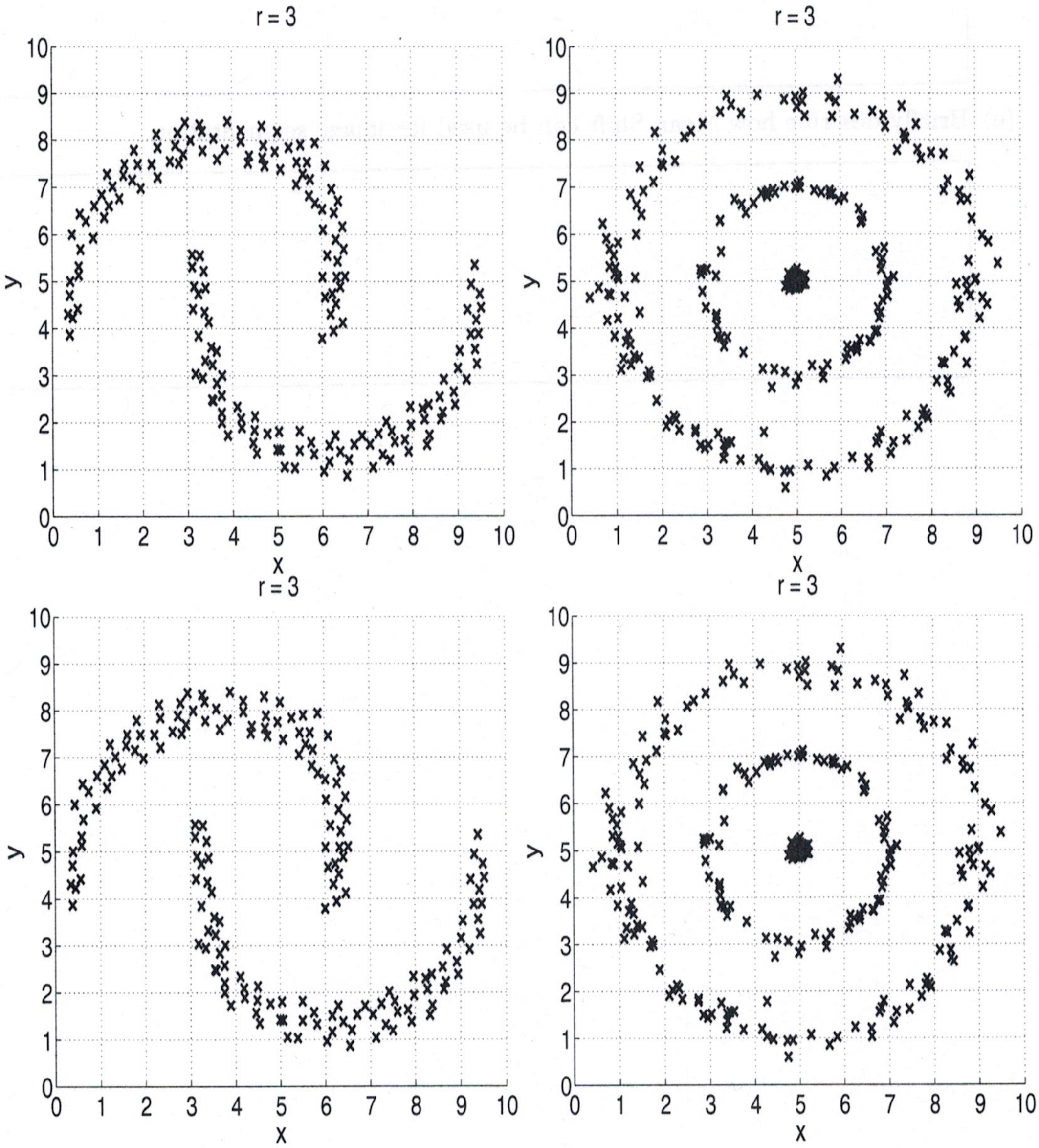
(f) Why is the Gaussian used for creating the pyramid? What would happen without this step? **(1 pt)**

(g) What is the Laplacian Pyramid? And how is it connected to the Gaussian Pyramid? **(1 pt)**

Question 2 .... **($\Sigma = 11$)**

(a) List the steps of the Mean-Shift algorithm. **(4 pts)**

(b) Sketch the (approximate) cluster boundaries and cluster centers Mean Shift would give for the following datasets with a windowsize of $h = 6$ (i.e. $h = 2r$). **(2 pts)**



(c) Briefly describe a strategy to speed up Mean-Shift. **(2 pts)**

(d) List two advantages and two disadvantages of Mean-Shift. **(2 pts)**

(e) Briefly describe how Mean-Shift can be used for image segmentation. **(1 pt)**

Question 3 ($\Sigma = 12$)

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

```
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. There are 2 steps missing. Please point them out (A verbal explanation is sufficient). **(2 pts)**

(c) Details to the Hessian detector.

i. What are the differences between the Hessian and the Harris detector. Please name two. **(2 pts)**

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

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

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

iii. How can Harris be extended to detect key points with arbitrary scale automaticaly. **(2 pts)**

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

(a) The Adaboost *training* algorithm.

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

ii. Briefly explain the steps of the Adaboost *training* algorithm. **(3 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. Fundamental Matrix **(1 pt)**

ii. Epipolar plane **(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 $(\mathbf{x}, \mathbf{y})$ where $\mathbf{x} = (x_1, x_2, 1)$ is located in the left image and $\mathbf{y} = (y_1, y_2, 1)$ 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. We usually solve this equation using SVD. Why? What exactly is the solution? **(1 pt)**

iii. Solving this equation directly usually leads to very inaccurate results in presence of noise. Please explain why. **(1 pt)**

iv. What can we do to about this issue in order to get more accurate results, and how? **(1 pt)**

(c) Rank constraints of the Fundamental Matrix.

i. What is the rank of the Fundamental matrix? Why? **(2 pts)**

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

iii. What can we do to prevent this (i.e. make sure we get the epipoles)? **(1 pt)**