

Only the calculator of the faculty may be used in the exam.

1. Let  $a \neq b$ . Which of the following signals are root signals of the median filter of length 3?

- a)  $\dots, a, a, a, a, a, b, a, a, a, a, a, \dots$  (1 point)
- b)  $\dots, a, a, a, a, a, b, b, a, a, a, a, \dots$  (1 point)
- c)  $\dots, a, a, a, a, a, a, b, b, b, b, b, \dots$  (1 point)
- d)  $\dots, a, b, a, b, a, b, a, b, a, b, a, b, \dots$  (1 point)
- e)  $\dots, a, a, b, b, a, a, b, b, a, a, b, b, \dots$  (1 point)
- f)  $\dots, a, a, a, b, b, b, a, a, a, b, b, b, \dots$  (1 point)

2. Consider the  $6 \times 6$  image

7	6	10	6	1	5
4	4	6	3	5	3
0	7	7	5	5	4
2	0	2	0	4	3
7	4	3	3	1	0
2	2	3	2	6	3

window

$x_1$	$x_2$	$x_3$
$x_4$	$x_5$	$x_6$
$x_7$	$x_8$	$x_9$

What is the output image of recursive stack filter of size  $3 \times 3$  and defined by the positive Boolean function  $f(\mathbf{x}) = x_4 x_5 x_6 + x_2 x_5 x_8 + x_1 x_3 x_5 x_7 x_9$ . No appending is required, but specify the scanning order that you have used. (6 points)

3. Does the Hodges-Lehmann D-filter coincide with the Wilcoxon filter when:

- a)  $N = 3$ , (3 points)
- b)  $N = 7$ . (3 points)

Justify your answers.

4. Assume that  $X^* = X_{k+1}$  and  $m$  is the sample mean. Write the definition

$$\text{LLMMSE}(X_1, X_2, \dots, X_N) = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_n^2} X^* + \left(1 - \frac{\sigma_s^2}{\sigma_s^2 + \sigma_n^2}\right) m$$

in the form of

$$b(X_1 + X_2 + \dots + X_k + aX_{k+1} + X_{k+2} + \dots + X_N).$$

This indicates that the LLMMSE filter is a weighted sum, with the center sample weighted differently from the others. When is the center sample given more weight than the other samples? (6 points)

5. Below is a part of the familiar test image used on the course and filtered versions of it. Give the corresponding output I1-I6 for each filter a-f. Size of the images is  $85 \times 165$  and the filter windows are  $5 \times 5$ .

- a) 10/25-trimmed mean filter (1 point)
- b) K-nearest neighbor filter ( $K = 9$ ) (1 point)
- c) ranked-order filter ( $r = 19$ ) (1 point)
- d) R1LH+ filter (1 point)
- e) harmonic mean filter (1 point)
- f) recursive median filter (1 point)

