

Only the calculator of the faculty may be used in the exam.  
 You can take the question paper with you.

1. How can you study
  - a) impulse response of a filter? (2 points)
  - b) step response of a filter? (2 points)
  - c) breakdown probability of a filter? (2 points)
  
2. a) Select two of these filters of length  $N$ :
  - $(r,s)$ -fold trimmed mean filter
  - center weighted median filter having center weight 5
  - basic FIR median hybrid filter
  - Wilcoxon filter
 Calculate two of the properties 1 a)-c) for these two filters. (4 points)
  - b) Which of the filters considered on the course is best for all situations? Justify your answer. (2 points)
  
3. Give a filter having window size  $3 \times 3$  that can preserve the corner below but at the same time remove the impulses ( $a$  and  $d$ ) when  $a < b < c < d$ ? (6 points)

Input image

$b$	$b$	$b$	$b$	$b$	$b$
$b$	$b$	$d$	$b$	$b$	$b$
$b$	$b$	$c$	$c$	$c$	$c$
$b$	$b$	$c$	$a$	$c$	$c$
$b$	$b$	$c$	$c$	$c$	$c$
$b$	$b$	$c$	$c$	$c$	$c$

Desired output image

$b$	$b$	$b$	$b$	$b$	$b$
$b$	$b$	$b$	$b$	$b$	$b$
$b$	$b$	$c$	$c$	$c$	$c$
$b$	$b$	$c$	$c$	$c$	$c$
$b$	$b$	$c$	$c$	$c$	$c$
$b$	$b$	$c$	$c$	$c$	$c$

window

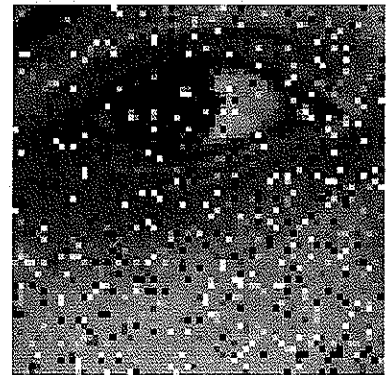
$x_1$	$x_2$	$x_3$
$x_4$	$x_5$	$x_6$
$x_7$	$x_8$	$x_9$

4. a) Show that the Boolean function  $f(x_1, x_2, x_3) = x_1x_2 + x_1x_3 + x_2x_3$  corresponds to the three point median filter. (3 points).
- b) What Boolean function corresponds to five point median? (3 points)

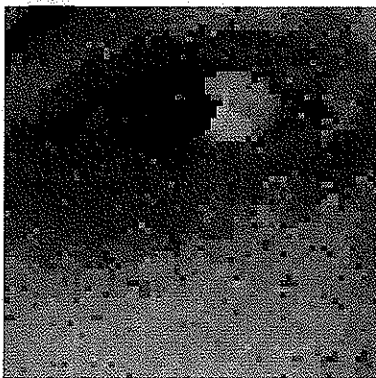
5. On the right is a part of the familiar test image used on the course and below are filtered versions of it. Give the corresponding output I1-I6 for each filter a)-f). Window size is  $5 \times 5$  if not otherwise specified.

- a) ranked-order filter ( $r = 7$ ) (1 point)
- ✓ b) R1LH+ filter (1 point)
- ✓ c) Hachimura-Kuwahara filter (the same 9 two-dimensional subwindows as on the course) (1 point)
- ✓ d) LUM sharpener ( $t = 6$ ) (1 point)
- ✓ e) opening (flat  $3 \times 3$  structuring element with the origin as its center) (1 point)
- ✓ f) recursive median filter (1 point)

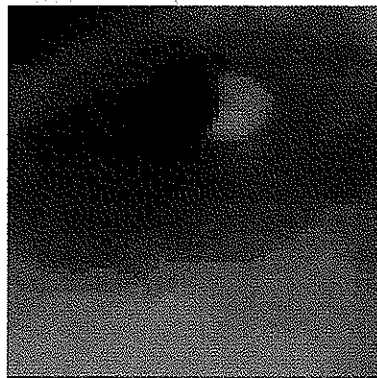
Noisy image



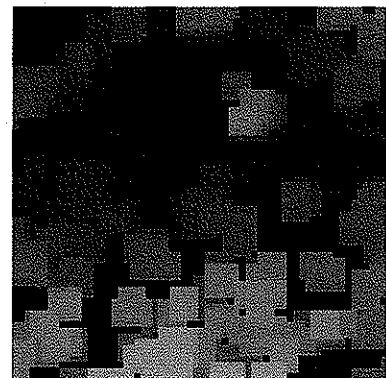
I1



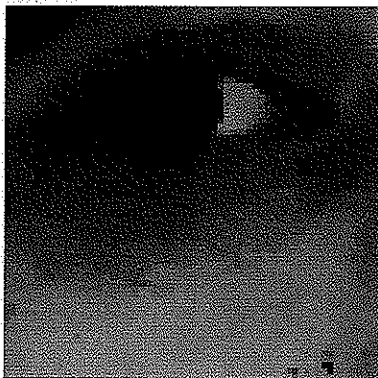
I2



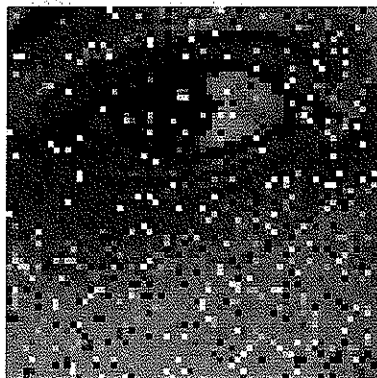
I3



I4



I5



I6

