The exam text is in English. You should answer the questions either in English or in Dutch. In either language and for all answers you should be **concise**! The exam consists of 4 questions (2 pages). Mark each answer with the question number and use a **new page** for each of the answers. Clarity in the arrangement of the answers is much appreciated as it greatly helps correction of the exam. All answer sheets as well as this question list should be handed in! Incomplete sets are not considered for correction and marking. The exam starts at 11.15 hrs and ends at 13.00 hrs. Participation in the exam requires being present for at least 1 hrs. Good Luck!

Question 1 (20 points)
Answer the following ten statements with correct/incorrect followed by a ONE-sentence motivation of the answer (motivation is required!!)

a) In an affine transform curved lines are straightened.
b) Deconvolution is an image restoration operation that removes imperfections from imaging.
c) An erosion operation removes pixels according to a predefined shape strategy; It is non-linear in that the reverse operation cannot always recover the original.
d) Registration is the process of annotating the image with valid labels.
e) The Bernsen threshold value is derived from the histogram data by triangulation of the peaks.
f) The Chamfer distance transform uses a different metric compared with the Euclidian distance transform.
g) The Top-Hat transform is a typical filter kernel defined by mathematical morphology.
h) In a binary image the Image Moments are derived from all pixels in the image and they can be used to describe a shape with a number of different features.
i) An Active Shape Model requires a first estimate of the contour to be optimized.
j) Watershed segmentation uses local intensity minima to find the watersheds.

Question 2 (8 points)
Edge detection can be accomplished in many ways. Specific filters have been designed to obtain edges as found in images. All of these filters have the characteristic that they enhance the differences in the intensities in the image.

a) Explain why edge detection is referred to as differentiation of the signal.
b) Give the characteristics of the Canny Edge Detector.
c) In parallel to the edge detectors derived from the Signal Processing theory, edge detectors are formulated in the domain of mathematical morphology. Explain how this can be achieved.

Question 3 (10 points)
Here is a string of freeman chaincodes representing a contour C with starting point S(x,y):
{10070777667553235666654443233200233321107}
The contour starts in S(x,y) in the clockwise direction.

a) Draw the contour on the answer sheet, in which one square represents a pixel.

The length of perimeter (P) of C can be well estimated from the so called corner-count algorithm: $L = 0.98 \cdot N_e + 1.406 \cdot N_o - 0.091 \cdot N_c$.

b) Explain the terms in the corner count algorithm and **compute** the Length of P of contour C.
c) Write an estimator for length L only taking into account the directions of the chaincode over the grid and **compute** L with that estimator. Explain the difference with the answer of 2b.

Simple geometrical transformations can directly be applied to the chaincode.

d) Develop an algorithm to rotate the contour C with 45 degrees that is directly applied to the chaincode of C and show how it transforms to C".

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Question 4 (7 points)
A particular image analysis application requires the density values from an image at sub-pixel locations. These values are obtained by interpolation. In Figure 1 part of an image is depicted. The grid-coordinates are shown along the x- and y-axis of the image. In order to obtain the density values at image coordinates (1.4, 1.4) and (2.7, 2.4) apply gray-level interpolation using:

a) Nearest neighbor interpolation; show how the result was obtained.
b) Bilinear interpolation; show how the result was obtained.

	1	2	3
1	2	3	4
2	3	4	5
3	5	7	3

Figure 1, part of an image with density values in the "pixels"