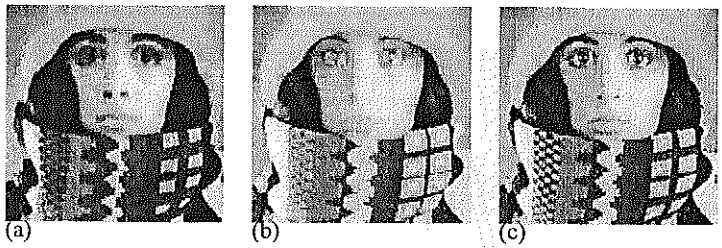
2 December 2009	**Image Understanding Exam**	16.00 – 17.30
Matr.Nummer: Kennzahl:	Nachname (Last Name): Vorname (First Name):	

The maximum number of points that can be obtained is 30. Please use the space provided for answering questions. The answers should be short but comprehensive. You may answer in English or German. **This is a closed-book exam.**

Bei der vorliegenden Prüfung können Sie eine maximale Anzahl von 30 Punkten erreichen. Bitte verwenden Sie den für die Beantwortung der Frage vorgesehen Platz und beantworten Sie die folgenden Fragen kurz aber aussagekräftig. Sie können die Fragen auf Englisch oder Deutsch beantworten. **Keine Unterlagen sind erlaubt.**

1 Mathematical Morphology

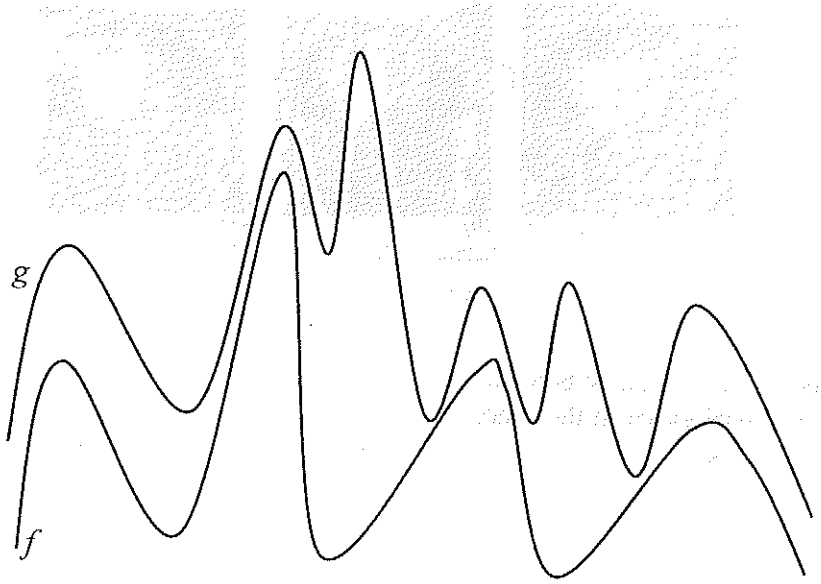
- Below are three greylevel images. One is the original image (size 128 × 128 pixels), one is the erosion of the original image and the other is the dilation of the original image. Both of these are done with a square structuring element of size 1. Write in the labels *original*, *erosion* and *dilation* below the images. (1 point)



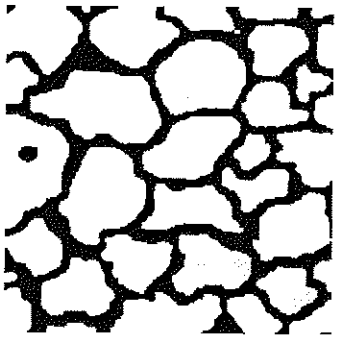
(a) ..... (b) ..... (c) .....

- Write the definitions of both the *white top-hat* and *black top-hat*. Why is it guaranteed that the pixel values in the results of these operators are always greater than or equal to zero? (1 point)

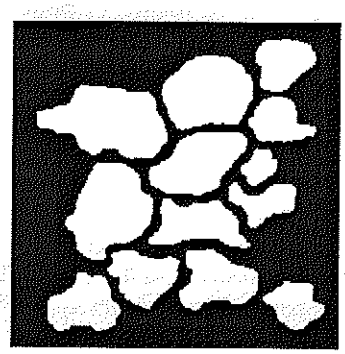
- Explain the morphological *reconstruction by dilation* algorithm. What are the roles of the *marker* and *mask* images? For the functions of one variable below, show the result of a morphological reconstruction by dilation of marker f inside mask g, i.e. $R_g(f)$. (2 points)



- Describe how you would produce binary image (e) below from binary image (d) below by making use of mathematical morphology. In other words, how would you remove the connected components touching the border of a binary image? (1 point)



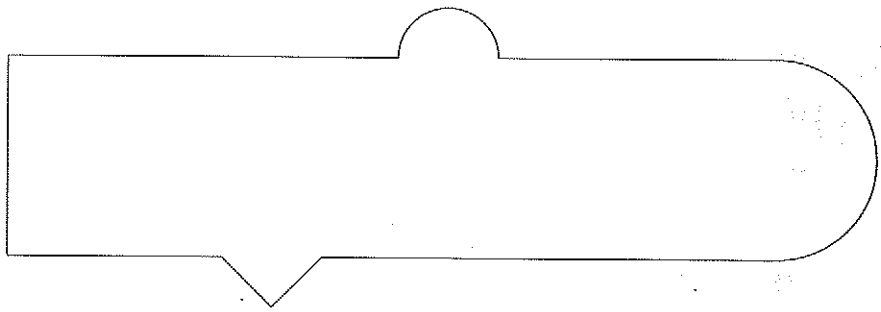
(d)



(e)

2 Skeletons

- Draw the Euclidean skeleton of the following shape (1 point):



- Which digital skeletonisation algorithm is guaranteed to produce a skeleton which is homotopic to the original shape? (Give only its name) (1 point)

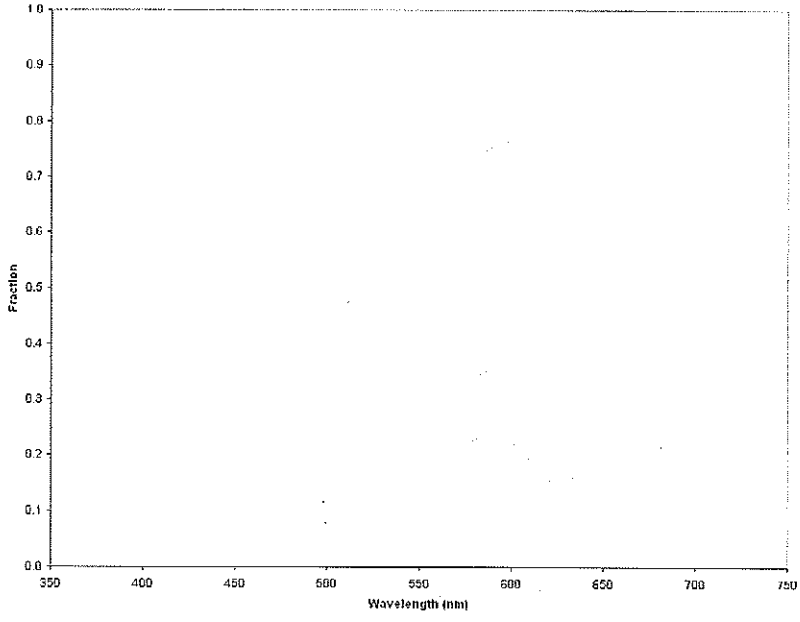
3 Greyscale image processing

- Write down any 3×3 convolution kernel which can be used to detect edges oriented in this direction \ in an image. (1 point)

4 Colour

- What are *false colours* in the result of a colour image processing operation? Under what conditions could false colours appear? (1 point)

- Draw, as a function of wavelength λ, what the transmittance $\tau(\lambda)$, absorption $\alpha(\lambda)$ and reflection $\rho(\lambda)$ could look like for a *green, translucent plastic material*. Use the axes below. Label the curves clearly. Don't forget the conservation of energy! (2 points)



- An electromagnetic signal in the visible light range with a spectral power distribution $\Phi(\lambda)$ arrives at the eye. Write down the equation giving the value extracted by the M cones, where $\mathcal{M}(\lambda)$ is the spectral response function of the M cones. (1 point)

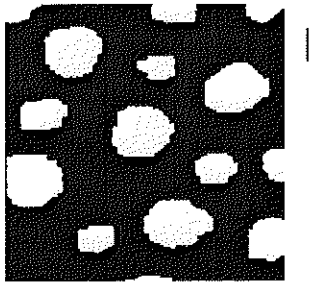
- (i) What is *computational colour constancy*? (ii) Describe the *von Kries model* and how it is used for computational colour constancy. (iii) Name an algorithm for estimating the colour of the illuminant and describe how it works. (3 points)

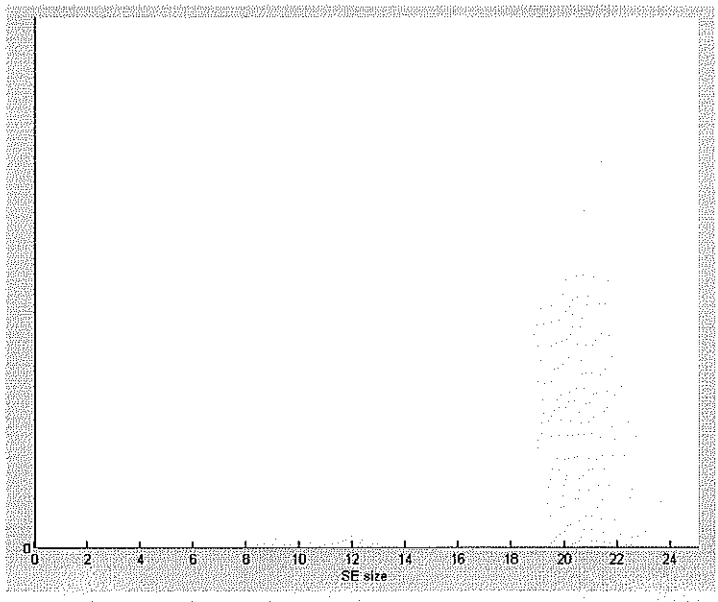
- Describe the CIELAB colour space: (i) List and describe briefly the steps in its derivation (equations are not necessary)? (ii) What is the main reason for which the CIELAB colour space is used? (iii) Which distance measure is used to measure the difference between colours in the CIELAB colour space? (3 points)

5 Texture

- Give the name of any texture analysis algorithm, except the granulometry. (1 point)

- Sketch an estimate on the axes provided of what the *pattern spectrum* of a granulometry by opening with a disc-shaped structuring element of the following binary image looks like. The *radius* of the structuring element is given on the x-axis. To help you out, the image is of size 256×256 pixels and the black line to the right of the image has length 30 pixels. (1 point)

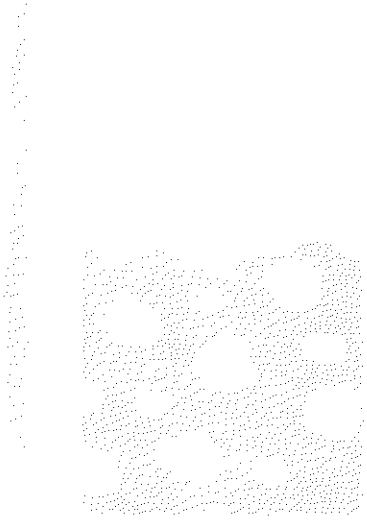




6 Segmentation

- What is the difference between *edge-based segmentation* and *region-based segmentation* approaches? (1 point)

- (i) Explain how the watershed segmentation algorithm can be modelled as a flooding of a topographical surface. Demonstrate how it works on a function of one variable. (ii) Explain why the watershed is seen as a combination of edge-based and region-based segmentation (3 points).



- The Watershed is well known for producing an over-segmentation if directly applied to a greyscale image (or to its gradient). List 3 approaches that can be applied to reduce this over-segmentation. (1 point)

7 CBIR and Object Recognition

- Given a certain query in a known image database, a CBIR system should return the 4 relevant images from the database. In fact, it returns 6 images, ordered by estimated relevance. The following table shows the ground truth relevance to the query of each returned image in positions 1 to 6:

position	relevant?
1	YES
2	NO
3	YES
4	NO
5	NO
6	YES

What is the *precision*, *recall* and $P(4)$, the *precision at 4 images* ? (1 Point)

- *R-Precision* is a retrieval metric defined as the Precision at R images, where R is the total number of relevant images for a query. Show that, in general, this is equal to the Recall. This shows why R-precision is usable as a single measure. (1 Point)

- What are *narrow image domains* and *broad image domains*? Give an example of each. (2 points)

- What is *relevance feedback* and how is it used to improve the results of CBIR? (1 Point)