**Technische Universität Berlin**


Computer vision &

Remote Sensing

Prof. Olaf Hellwich

**Examination**

# Digital Image Processing

**Name**: .....  **Student ID**: .....

**Duration**: 1 hour  **Auxiliary material**: None

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Berlin, July 13, 2010

# 1 Interest Points (15P)

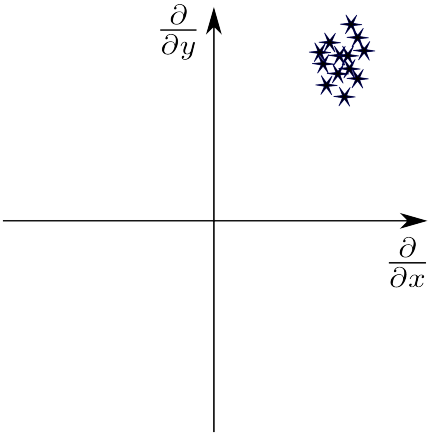


Figure 1

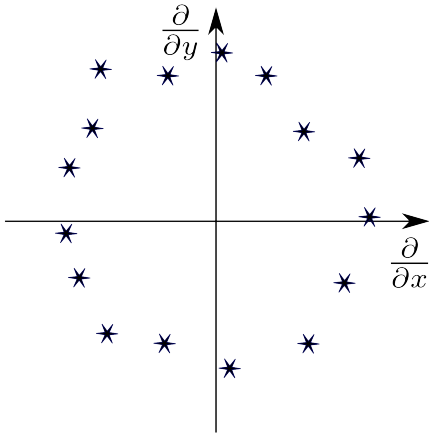


Figure 2

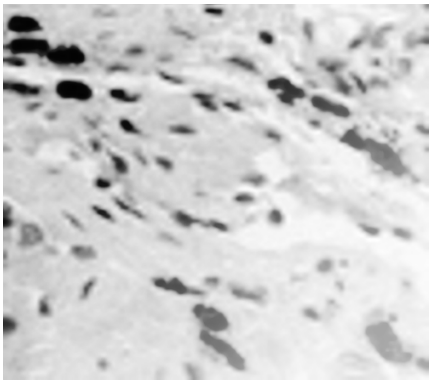
a) The detection of so-called interest points in grey scale images begins with the computation of partial derivatives $\frac{\partial}{\partial x}$ and $\frac{\partial}{\partial y}$ of the image intensity. Give a detailed, step-by-step description of an algorithm to carry out this computation. Assume that convolutions are to be carried out in the frequency domain and define any filter kernels required. (6P)

b) The resulting gradient vector associated with each pixel of an image has a direction as well as a length (magnitude). Give an interpretation of both of these quantities and state how the gradient magnitude is computed from the partial derivatives $\frac{\partial}{\partial x}$ and $\frac{\partial}{\partial y}$. (3P)

c) Interest point detectors generally analyse the distribution of gradients in the neighbourhood of each pixel in a given image. Figures 1 and 2 above show plots of this distribution for two particular pixels: each point represents the gradient vector associated with a pixel in the neighbourhood. The gradient magnitudes can, in both cases shown, be considered large. State what type of image structure each neighbourhood corresponds to and sketch a neighbourhood (in terms of image intensities) that could have given rise to each gradient distribution. Your sketches should indicate the $x$ and $y$ axes and their direction as well as which parts of the neighbourhood are bright (large intensity) and which are dark (small intensity). (6P)

## 2 Segmentation and Morphology (13P)

A hospital intends to automate certain diagnostic procedures that are currently carried out manually and are therefore time consuming and ultimately expensive. The most important of these procedures is the discrimination of certain tissue samples into the classes *healthy* and *pathological*. In the particular case considered, the diagnosis depends strongly on the spacing of cell kernels: a significantly large distance between neighbouring cell kernels indicates a potentially fatal medical condition. An example histological sample is shown in the figure below. The chemical markers used in this type of sample make cell kernels appear as dark spots.



a) The first step in the automated analysis is to accurately segment the cell kernels (dark regions). Due to suboptimal illumination conditions during image acquisition, sample images frequently exhibit a pronounced intensity modulation (an intensity gradient from the top left to the bottom right in the example shown above). Explain why a histogram based segmentation algorithm will often fail to accurately segment cell kernels in these circumstances. (2P)

b) Suggest a region growing segmentation algorithm based on the gradient magnitudes in the input image. Give a step-by-step description of the proposed algorithm and explain why it is more likely to provide acceptable results. The result of the proposed algorithm should consist of one segment per cell kernel (foreground segments) and a single, large segment encompassing the surrounding tissue (the background). (5P)

c) The distance transform is a morphological operator frequently applied in the analysis of binary images. What does it compute? (2P)

d) Suggest an algorithm that uses the distance transform to estimate the average separation of cell kernels in a given histological sample. The input to this algorithm is a binary image in which values $1$ and $0$ indicate pixels in cell kernels (foreground) and tissue regions (background), respectively. The output is a single number that roughly corresponds to the average distance, in pixels, from the edge of one cell kernel to the edges of its closest neighbours. Provide a sketch to clarify your description if necessary. (4P)

## 3 Super-Resolution (5P)

Super-resolution algorithms combine several low-resolution images of the same scene to produce a single high-resolution image.

a) Briefly outline the three processing steps involved in most super-resolution algorithms. (3P)

b) Give an intuitively appealing explanation as to why the input low-resolution images must be aliased (i.e. why the sampling theorem must be violated during their acquisition). (2P)

A total of **33 Points** is to be attained.
**Good Luck!**[1]

[1] We hope you will not need it.