![CV logo]

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Computer Vision &
Remote Sensing

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Examination

Digital Image Processing

Summer Term 2013

Name: ....

Student ID: ....

Duration: 1 hour

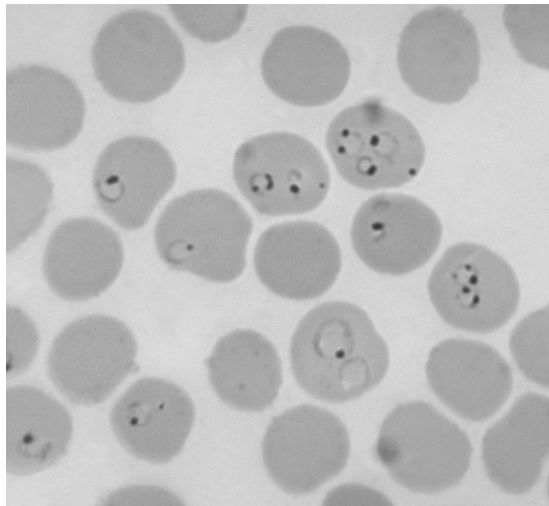**Auxiliary material:** None

Berlin, July 16, 2013

Figure 1

A medical scientist works on a system to automatically detect malaria parasites in microscopic images of red blood cells.

Figure 1 shows such an image of red blood cells. Several of them are infected with ring-stage malaria parasites.

Credit: Dr. Mae Melvin
U.S. Centers for Disease Control and Prevention

1 Image Properties   9P
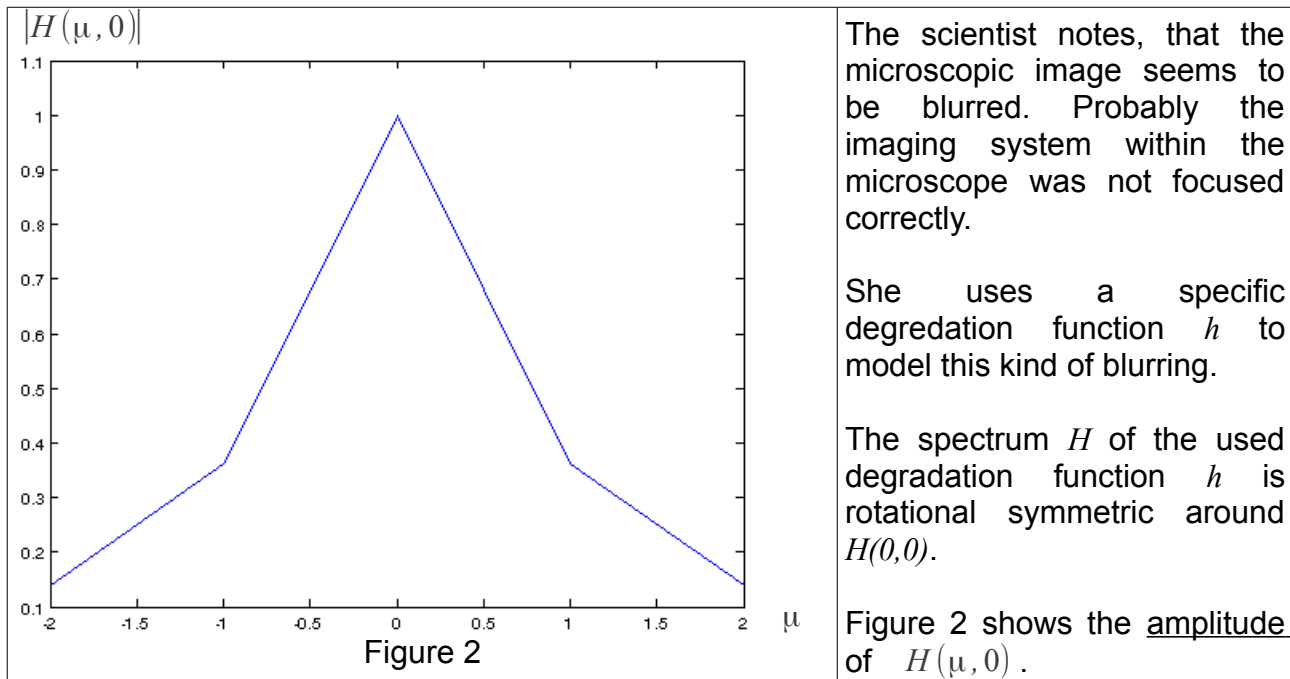
The scientist starts her work with judging general image properties based on the relative gray-value histogram of this image.

a) Explain how this kind of histogram is calculated from a given image.   (2P)

b) Sketch the relative histogram of the image in Figure 1.   (2P)

c) In the following three different pairs of statements are given. For each pair give a brief explanation which of the two statements is more likely to be true, based on the histogram from question 1b).   (3P)

   i)   „The image is bright." **or** „The image is dark."
   ii) „The image has low contrast." **or** „The image has high contrast."
   iii) „The image mainly consists of a homogeneous fore- and background." **or** „The image contains many different heterogeneous objects."

d) Explain a simple method how the contrast of an image can be enhanced.   (2P)

2 Image Restoration   8P

Figure 2

The scientist notes, that the microscopic image seems to be blurred. Probably the imaging system within the microscope was not focused correctly.

She uses a specific degredation function h to model this kind of blurring.

The spectrum H of the used degradation function h is rotational symmetric around $H(0,0)$.

Figure 2 shows the amplitude of $H(\mu,0)$.

a) Based on this frequency spectrum, which filter function does he assume
   to have caused the blurring?   (1P)

b) Draw the one-dimensional part $Q(\mu,0)$ of the amplitude spectrum Q of the
   inverse filter q based on the degradation shown in Figure 2.   (1P)

c) Which conditions need to be fulfilled by the image acquistion process,
   if the inverse filter is able to lead to a good restoration?   (3P)

d) If the conditions from 2c) are not fulfilled, the application of the inverse
   filter is problematic. Explain how the inverse filter has to be adapted
   to circumvent at least some of these problems.   (1P)

e) Another possibility would be to apply the Wiener filter. The scientist is afraid
   that the signal model of the image might be $s=h(o){\cdot}n$, where s and o are the
   measured and original image, respectively, h is a shift invariant filter and n is a
   Gaussian noise term with mean value $\mu=1$. In this case the Wiener filter
   cannot be applied directly.

   i) Explain why.   (1P)
   ii) Which simple image transformation can be used
       to make the Wiener filter applicable in this case?   (1P)

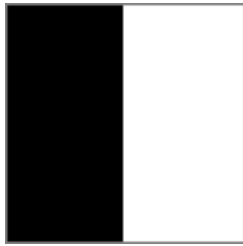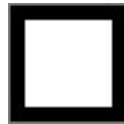# 3 Correlation   6P

After the scientist finally finished the preprocessing steps of image enhancement and image restoration, she starts to investigate how to automatically interprete the image. Her first try is to correlate the given image with several template images of the parasites.

a) How is the correlation theorem defined and why is it useful?   (2P)
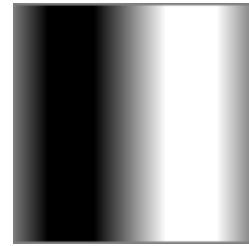

a)   b)   c)

Figure 3

b) The image in Figure 3a) was correlated with the image in Figure 3b) by
   using the correlation theorem. The result is shown in Figure 3c).
   Give a detailed <u>explanation</u> of the border effects.   (2P)

c) <u>Explain</u> how the resulting image would differ if a convolution instead of
   a correlation would have been applied?   (2P)

4 Graphical Models   7P

The direct template matching approach turned out to be unreliable. Too many false matches were found outside of the blood cells. The scientist considers to segment the image in order to restrict a subsequent search for parasites only to the interior of blood cells. He read that image segmentation can be achieved by representing the image as a special kind of Graphical Models: a Markov Random Field (MRF).

a) <u>State</u> which properties a Graphical Model needs to fulfill to be a MRF.   (2P)

b) <u>Sketch</u> a simple MRF as it is usually used in image processing applications.   (1P)
   Name all important elements of an MRF in your sketch.   (2P)

c) If Figure 1 shows a typical image in this application, would you recommend
   to use an MRF for segmentation or would you suggest another method?
   <u>Give reasons</u> for your answer.   (2P)

5 Morphology   5P

After some trials the scientist was able to achieve a good automatic segmentation, in which each cell is represented by an individual segment. However, in some cell segments are small holes, which correspond to local intensity variations. The scientist wants to apply a morphological operator, in order to close those holes without changing the size of the cells.

a) Which morphological operator should the scientist use for this purpose?   (1P)

b) Give a <u>definition</u> of this operator. If you use other morphological
   operators in this definition, please define those as well.   (3P)

c) <u>Apply</u> this operator with the structuring element given in Figure 4a) to the   (1P)
   binary image in Figure 4b).
   The area outside of the image in can be assumed to be zero.
   The anchor point of the structuring element is denoted in bold type.

0	1	0
1	1	1
0	1	0

a) Structuring Element

1	1	1	1
1	0	1	0
1	1	1	0

b) Image

Figure 4

6 Interest Points   6P

Finally the scientist is able to work on the detection system, which will only process the interior of the segmented cells. He notices, that the image area of almost all parasites is dominated by a dark point-like structure. His plan is to detect this structure with the Förstner interest operator.

Give a <u>detailed step-by-step explanation</u> how to find interest points in an image
with the Förstner operator.   (6P)

A total of **41 points** can be attained.

A short and accurate style as well as a clear handwriting should be intended.
Pay attention to a clear and comprehensible preparation of sketches.

Lot's of luck and do your best!