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SCHOOL OF ENGINEERING

# Test for Medical Engineering Self Assessment

For prospective master students

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# Basics of Object-Oriented Programming

1.) Which of the following statements about Interfaces in *Java* are correct?

- ◯ An `Interface` can inherit from `Classes`.
- ◯ An `Interface` can not inherit from more than one `Interface`.
- ◯ An `Interface` can be extended using the keyword `extends`.
- ◯ An `Interface` can be extended using the keyword `implements`.

2.) Which of the following statements about Object-Oriented Programming in *Java* are correct?

- ◯ Every constructor of a sub class always implicitly calls the corresponding constructor of the base class at first.
- ◯ In order to inherit properties from multiple classes, a *Java* class can extend from multiple bases classes.

# Computed Tomography: Beer-Lambert Law

1.) Describe the law and name its formula.

2.) The CT reconstruction task consists in obtaining the absorption coefficients from the measured intensities I. Solve the formula for the line integral over the absorption coefficients.

3.) Which function does the CT reconstruction image represent?

# Computed Tomography: Hounsfield Scale

The Hounsfield Scale is a linear transformation of the original linear attenuation coefficient measurement given by

$$[\text{HU}]\mu_x = \frac{\mu_x - \mu_{water}}{\mu_{water} - \mu_{air}} \cdot 1000\,\text{HU}$$

1.) Given this formula you can easily calculate the HU of water and of air. What are the respective Hounsfield units?

2.) The Hounsfield scale is commonly used in the range from -1024 (which is close to the absorption coefficient for air) to 3071. This is equal to a range of 0 to 4095, i.e. 4096 values. Which bit encoding does this exactly correspond to?

# Computed Tomography: Hounsfield Scale

3.) CT images whose pixel values are measured in HU which can have negative values are commonly stored with an unsigned integer. If you are given a CT image stored with a value range from 0 to 4095 you need to specify a linear transformation from pixels in their stored on disk representation to their in memory representation. Suggest sensible values for the slope and intercept of the following linear transformation when the target range is in the standard HU range from -1024 to 3071.

4.) Imagine you are given a CT image of a patientâ€™s brain who suffers from ischemic stroke. The values of your CT image are correctly rescaled and thus range from -1024 to 3071 HU. The range you are mostly interested in ranges from 0 to 80 HU. What do you need to do when plotting the image in order to be able to see the stroke region? Be aware that the human eye can only distinguish small ranges of the whole Hounsfield scale.

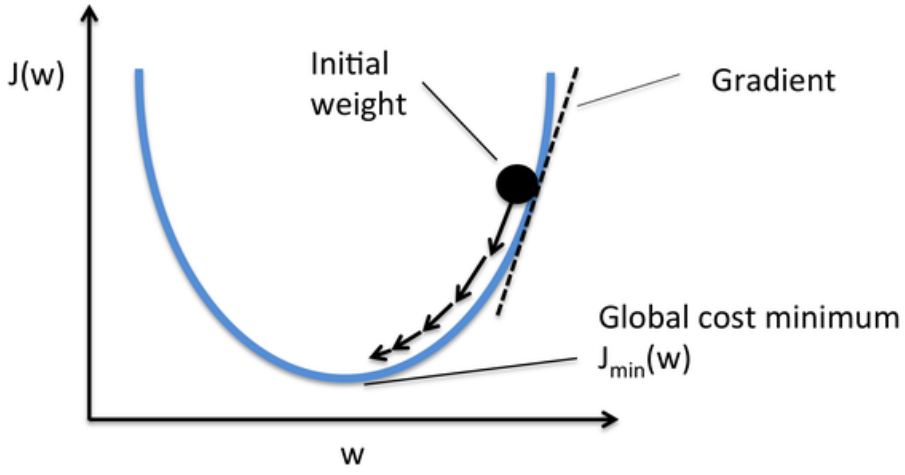
# Optimization

1.) You are given a convex function, e.g. $f(x) = 3x^2 + 2$. How do you compute the minimum of such a function analytically?

2.) Can you name an iterative approach to minimization?

3.) How do you introduce a constraint into an optimization function?

# Optimization




4.) Name and explain the update rule of the gradient descent including all its parameters.

# Optimization

5.) What happens if the learning rate is chosen too large? Provide a sketch for this situation.

6.) What changes if you have a non-convex function that you are trying to minimize? Sketch examples of both a non-convex function in contrast to a convex function.

7.) Explain the influence of choice of initial weights in a non-convex function on the result.

# Convolution

1.) Name the formula for convolution in discrete space.

2.) Name the convolution theorem and the mathematical properties of convolution.

3.) Can you think of a reason why the convolution is preferably computed in Fourier space?

# Filtering

1.) When you convolve an image with a filter kernel you can enhance and detect certain features of your image. Depending on the choice of your filter kernel you can sharpen or denoise an image or detect edges in various orientations. Give an example of an edge filter in 2D matrix form and be able to explain it.

2.) What is the formula of the Gaussian filter in 2D?

3.) Correlation uses the same mathematical operation as convolution except that in convolution the filters are flipped. When is the correlation result exactly similar to the convolution result?

# Denoising

You are given a noisy acquisition of an image and have no prior knowledge about the distribution of the underlying noise. You apply a standard denoising algorithm, e.g. Gaussian filtering to the noisy image however your output image, the denoised estimate does not show obvious improvements over the noisy image.

1.) Before trying other denoising approaches which possibilities do you have to visually compare your output with the original noisy image?

2.) Which metrics could you calculate to compare your image to the noisy image?

# Linear Algebra

1.) Suppose we have the following matrix equation. What are $x_1$ and $x_2$?

$$\begin{bmatrix} 1 & 2 \\ 2 & 5 \end{bmatrix} \times \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}$$

2.) What is a Pseudoinverse?

3.) How many real eigenvalues does a given rotation matrix have (assuming the matrix is nontrivial, i.e. not the identity)?

4.) When is a matrix positiv-semidefinite?

5.) Explain the Lipschitz continuity.

6.) How do you solve a linear system of equations?