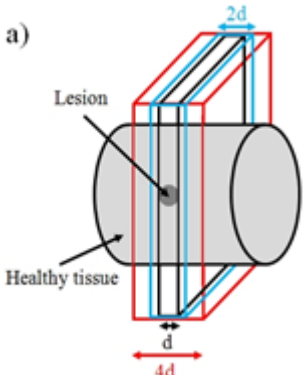
Problem 1 – SNR vs. Contrast

Three slices of an organ with a lesion are acquired with an imaging device. The position and field of view of each slice are similar. The thickness of the first slice is d, whereas 2d and 4d are chosen for the second and third ones (a). The pixel values recorded for each acquisition are presented in (b), (c) and (d).



Remarks: (i) One can assume the noise per pixel as constant throughout the images. (ii) The signal increases linearly with the slice thickness.

Which acquisition provides the highest:

1) SNR?
2) Contrast between lesion and healthy tissue ($Contrast_{A-B}=S_A-S_B/S_A+S_B$)?
3) CNR between lesion and healthy tissue?

b)

1	1	1	1	1
1	5	5	5	1
1	5	10	5	1
1	5	5	5	1
1	1	1	1	1

Thickness = d

c)

1	1	1	1	1
1	10	10	10	1
1	10	15	10	1
1	10	10	10	1
1	1	1	1	1

Thickness = 2d

d)

1	1	1	1	1
1	20	20	20	1
1	20	25	20	1
1	20	20	20	1
1	1	1	1	1

Thickness = 4d

Problem 2 – Voxel Size vs. SNR

In imaging and spectroscopic experiments, signals from 3-dimensional parts ('voxels', i.e. 3D pixels) of the object of interest are localised, i.e. can be differentiated in space. The size of a voxel (usually given in cubic mm) defines thus the spatial resolution of the experiment. Let's now assume that the signal strength in a single (isotropic, i.e. all edges have the same length) voxel is proportional to the number of molecules in it. A high spatial resolution is preferable, so one wants to reduce the voxel size.

a) How does the signal change if the edges of the voxel are reduced by 20%/50%/80%?
b) What could be a possible solution to keep the original SNR (and the price to pay)?

Problem 3 – Optimising CNR

In magnetic resonance imaging (MRI), one important time constant characterising biological tissues is the so-called T_1 time. After excitation (how this exactly works will be explained later in the course), the tissue signal recovers according to $s_{tissue}(t) = 1 - e^{-t/T1}$

In biomedical imaging, it is often crucial to be able to differentiate between different tissues. In a human brain imaging experiment, we want to observe two different brain tissues: gray matter ($T_{1,GM}$ = 1300 ms) and white matter ($T_{1,WM}$ = 800 ms).

a) Express in words what the CNR (Contrast to Noise Ratio) is and give its formula. What is the difference with SNR?
b) Calculate the time t_{max} after the excitation when one should measure the signals from gray and white matter to obtain the best CNR between the two (assume noise to be constant).
c) Discuss how the SNR influences this experiment. Is it preferable to have maximal CNR or SNR in the given experimental setup?