2. Fourier Analysis

1. What is the Fourier transform of a comb function? How is it used in digital signal processing?
2. Name convolution-based reconstruction kernels and point out their advantages
3. Explain the Gibbs phenomenon.
4. When is a Fourier series real?
5. What is the Fourier transform of the box function and how is it used in digital signal processing
6. Describe the power spectrum of a square.
7. How can we implement a low/high-pass filter using the Fourier transform?
8. Describe the mathematical model of sampling
9. Why does aliasing happen and how is it visible in images?
10. What does Nyquist theorem state

3. Magnetic Resonance Imaging

1. What do T_1, T_2, T_2^* times have in common?
2. Name and explain briefly how each spatial dimension is encoded in MR imaging.
3. State an important difference and its implication between traditional MRI and Echo-planar imaging.
4. Name the main components of a MR scanner
5. What physical property is the basis of MR signals
6. What is the Larmor Precession? Give its formula.
7. Describe the typical sequence to acquire a T_2 image. include terms: TE, TR, RF pulse, field gradient
8. How can we select a slice in the z-dimension?
9. Explain T_1 time and the corresponding relaxation.
10. Explain T_2 time and the corresponding relaxation.
11. Why do we typically do not get the T_2 time from a MR scan?
12. What are the benefits of a gradient recalled echo
13. Name some safety issues in MRI
14. Explain the dimensions of the k-space
15. How do we get a brain image from the k-space
16. Give to MRI artifacts and explain them.

4. Registration

1. Affine transformations have 12 DoF. What kind of geometric transformations do they permit.
2. $NMI = \frac{H(X) + H(Y)}{H(X,Y)}$

   What does each component stand for?

   Why do discontinuities arise in their computation and how can we adress them?

   In which case would you consider NMI?

   What algorithm could be used to maximize it?
3. How are nonlinear image transformations regularized in elastic registration
4. Explain the two main paradigms to compute a transform for registration.
5. Name two registration evaluation techniques
6. What is the problem with anisotropic voxels
7. Name two cost functions for intra-modality registration
8. Explain the main steps of the Nelder Mead method
9. How can we integrate prior knowledge to Nelder Mead?
10. How are transformations defined in a deformation field?
11. What are the assumptions of non-linear regression?
12. Name two non-linear optimization techniques
13. How does the PASHA algorithm regularize?
14. How does the Demon algorithm regularize?
15. Define a diffeomorphic transformation.

16. How can we use an atlas to label images

17. Explain how we can create our own template.

5. Segmentation

1. What happens in the M step of a GMM?
2. State the advantages of combining a GMM and MRF.
3. Describe the U-net and state a difference to FreeSurfer.
4. State two different usages of segmentation in neuroimaging
5. Name and state a metric for segmentation evaluation.
6. Describe the idea of deformable contours
7. What do we regularize in deformable contours and how do we do it?
8. How can we compute the local curvature between vertices
9. Explain k-means clustering.
10. Explain how GMM are used for segmentation
11. Explain the E-step for GMM
12. How can we define prior probabilities with MRFs
13. How can we incorporate MRFs in the EM algorithm
14. Explain the Max Flow-Min Cut dualism.
15. How is a cut defined?
16. How do we construct a Max-Flow graph
17. Explain alpha expansion.
18. What is a bias field and its assumptions
19. How can we model non-tissue classes in segmentation?

6. Statistical Testing

1. What is a type I and II error? How do they relate to the frequently used level $\alpha = 0.05$
2. Why is Bonferroni correction overly conservative? Name a more sensitive but still valid alternative
3. Briefly explain the role of the modulation step in VBM.
4. Explain the basic setup of hypothesis testing.
5. Explain the p-value and how to interpret it.
6. What are t-tests used for?
7. Explain the steps of a single-sample t-test
8. Explain the steps of a two-sample t-test
9. What distribution does t follow and why
10. What can we do, if our two samples have diff variance?
11. Explain a paired t-test
12. What are family-wise errors and why do we have to consider them?
13. Explain the steps of ANOVA
14. What is the random field theory used for
15. Why can cluster-based tests help with family-wise error
16. Explain the idea of Threshold-Free Cluster Enhancement
17. Explain the steps of VBM

7. Functional MRI

1. Does the BOLD effect increase or decrease the MR signal, explain why.
2. Name four operations that are performed while pre-processing fMRI data.
3. Point out three errors in the following spectral clustering algorithm:
   - Compute Laplacian $L = DW$
   - Compute the eigenvector $\mathbf{v}$ corresponding to the smallest eigenvalue of L
   - Let θ be the median of the v_i
   - Assign node i to cluster 1 if $v_i \geq \theta$, to cluster 2 if $v_i < \theta$
5. Explain the typical timecourse of a BOLD signal
6. What are the assumptions of a hemodynamic response and how might these be violated
7. How do we model the HRF and use it to get our BOLD timecourse
8. Explain the main idea of GLM
9. How can we design a statistical test testing for a BOLD signal using GLMs
10. Explain the typical steps in a fMRI pipeline
11. Name two pitfalls in fMRI
12. What is the general task in rs-fMRI
13. Name two typical goals/motivations in rs-fMRI
14. What is the difference in usage of GLM and ICA
15. Explain the basic principles of ICA and how it relates to fMRI
16. Give a cost function for cuts used in group-analysis
17. What is our goal in fMRI group analysis
18. Name two neighborhood graphs

8. Diffusion MRI

1. What could a decreased FA value indicate in comparison to a healthy control group
2. Explain the difference between VBM and the statistical analysis in diffusion tensor imaging.
3. Name a mathematical model for estimating fiber direction per voxel and explain why such models are needed
4. Explain the physical principle that allows us to measure diffusivity
5. Explain the process of measuring the diffusivity
6. Explain the diffusion tensor model
7. How can we get the direction of white matter tracts from a diffusion tensor
8. Name the main parameters used for statistical analysis
9. Why can't we use our typical brain analysis approach in diffusion MRI
10. Explain the steps of TBSS to build a statistical map
11. Name the components required for fiber tracking
12. Explain how fibers typically cross
13. How can we perform multi-fiber tracking
14. Name a strategy to model multi-tensor models
15. Name advantages and disadvantages of multi-tensor model
16. Name the basic assumption of spherical decon.
17. Name advantages and disadvantages of the spherical decon

9. Machine Learning

1. SVMs can be trained in its primal and dual form. Why is the dual form often preferred? In which case would you prefer the primal form?
2. Why are features often normalize? Describe one of such method.
3. State the task of supervised learning
4. Explain cross-validation and when to use it
5. Give the formula for accuracy, precision or recall
6. How does a SVM find a separating hyperplane?
7. State the primal definition of a SVM.
8. How can we allow missclassifications in SVMs
9. Explain the kernel trick in SVMs and why it is used.
10. Why would we select specific features?
11. Describe a feature selection method
12. Name an example where learned classifiers are used