(Bitte schreiben Sie Ihren Namen auf jedes Blatt)

1.) Wie können Sie eine Methode zur Detektion einer Pathologie (Klassifikation jedes Datensatzes) validieren? Geben Sie zumindest ein Mass fuer Validierung unter Verwendung von Ground-truth und zumindest ein Mass ohne Notwendigkeit von Ground-truth an?

2.) (a) Was sind die Auswirkungen der beiden Terme in der Energiefunktion für explizite Snakes auf den resultierenden Verlauf? (b) Sie muessen die schwarzen Strukturen in nebenstehendem Bild segmentieren, welche Snakeformulierung verwenden Sie? Warum?

3.) Welche Vorbereitung ist notwendig um eine modellbasierte Suche nach einer anatomischen Struktur in Bild oder Volumsdaten durchzufuehren? Beschreiben Sie den Unterschied zwischen Active Shape Models und Active Appearance Models (geben Sie zumindest einen Punkt bzgl. des Models, und einen Punkt bzgl. des Trainings an)

4.) Was wird bei fMRI gemessen, und über was gibt es Auskunft?

5.) (a) Skizzieren Sie die beiden Verteilungen von Punktemengen A bzw B in einem 2-dimensionalen Raum. Die beiden Verteilungen haben die folgenden Kovarianzmatrizen. (b) Auf welchem der beiden Datensätze macht PCA Sinn (d.h auf welcher der beiden wuerde PCA das Koordinatensystem veraendern)?

$$A = \begin{pmatrix} 4 & 0 \\ 0 & 1 \end{pmatrix} \qquad B = \begin{pmatrix} 3 & 1 \\ 1 & 2 \end{pmatrix}$$

6.) Was ist der Unterschied zwischen *General Linear Model* und *Multi Voxel Pattern Analysis*? (geben Sie 2 Punkte an). Sie untersuchen fMRI Daten, und moechten die Hypothese ueberpruefen, dass waehrend des tasks, den die Person im fMRI Scanner durchfuehrt in erster Linie Synchronisierungsmuster zwischen Hirnregionen auftreten. Welche der beiden Methoden ist fuer diese Fragestellung relevant? Warum?

7.) (a) Welche Materialeigenschaft wird mit CT gemessen, in welcher Einheit? (b) Welche Modalität koennen Sie verwenden um Nervenfasern abzubilden?

8.) In welcher Weise unterscheiden sich Graph Cuts von Snakes, was haben sie gemeinsam?

9.) (a.) Ausgehend von einer korrekten Registrierung zweier Datensätze wird ein Datensatz verschoben d.h. ein künstlicher Fehler erzeugt. Wie wirkt sich das auf das Maß bzw die zugrundeliegende joint probability distribution der Voxelwerte aus? (b.) Sie muessen einen CT Datensatz mit einem PET Datensatz registrieren. Beide Datensätze zeigen das Gehirn derselben Person. Welches Similaritätsmass wenden Sie an um den Unterschied zwischen registriertem und fixem Bild zu berechnen? Welche Optimierung ist fuer die Registrierung geeignet? Welche Deformierungsart ist einsetzbar? Begründen Sie jeweils Ihre Wahl.

10.) Welche der beiden Modalitäten hat eine höhere zeitliche Auflösung: MEG oder fMRI? Welche hat hoehere räumliche Auflösung? Was wird mit MEG gemessen?

1) Man kann Methoden in erster Linie natürlich anhand einer ground-Truth validieren. Hierbei wird ein Similaritätsmass angewandt. Dieses kann sein

- SSD (Sum of squared differences)
- SAD (Sum of absolute differences)
- CC (Cross-Correlation)

} zu Ground Truth

Ohne ground truth kann man mit einem Standard of Reference validieren, bzw. stehen einem immer folgende Masse zur Verfügung:

•)

Gefunden	Pathology / Disease: True	Pathology / Disease: False
Pos.	TP	FP
Neg.	FN	TN

Sensitivity = $\frac{TP}{(TP+FN)}$ Specificity = $\frac{TN}{(TN+FP)}$

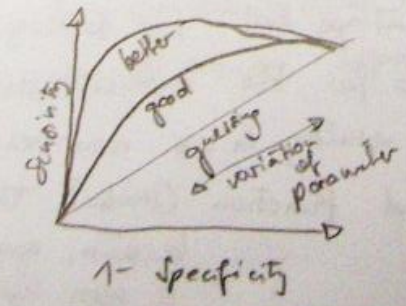
Es müssen Sensitivity & Specificity angegeben sein, sonst hat er keine Aussage!

•) ~~False~~ ~~True~~ - Negative - Rate = 1 − Sensitivity
~~False~~ ~~True~~ - Positive - Rate = 1 − Specificity

•) $\frac{TP+TN}{TP+FN+FP+TN}$

•) Area under the curve (AUC)

A parameter [redacted] with great resulting change in the outcome is varied to find the following relationship:

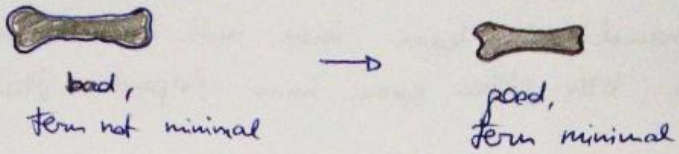


The bigger the area under the curve is, the more (precise) accurate is the method!

2) a) Die beiden Terme der Energiefunktion:

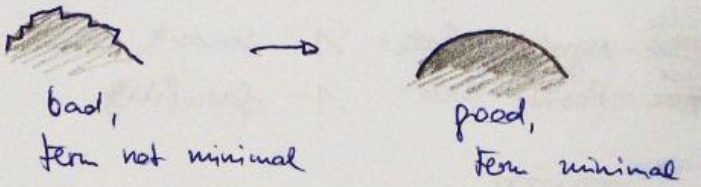
•) explicit → image properties (journeys along low gradient paths are being penalized)

→ if the explicit term is not as small as it can be i.e. not minimal, then the ~~contour~~ path doesn't describe the shape of the segmented object very accurately but is probably still "a little too far out".

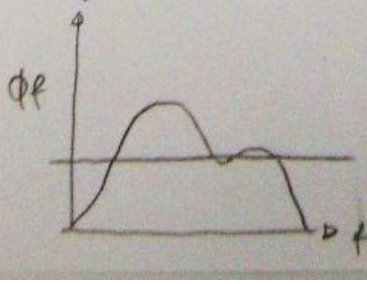


•) implicit → contour properties (elasticity and rigidity (i.e. first and second derivatives) of the path are being penalized)

→ if the implicit term is not minimal, the ~~contour~~ path is not „smooth, but rather ragged and might not represent the true, (if physiological usually smooth) contour of the object.



b) I would use the explicit snake (i.e. active contours) because the ~~gras~~ object exhibits high contrast to the texture of the surrounding area so there is a high gradient to be found and the snake is not likely to form ragged (unsmooth) paths. However, this bears the disadvantage that my topology and resolution is fixed, so I think I do go for the implicit snake. There, a zero level set is made, resulting in a non-resolution dependend and non-topography dependend function (snake). This can be done because, again, the contrast is very high and should yield a very accurate result.



3) I need sample images of the object that I want to model, plus a doctor and some of his time to manually segment a number of those images. The resulting model is tested on all sample images.

An important step is to train the model to make up for rotation, translation, shear and scale (normalization). In AAM's this is done by either of those two methods:

-) Regression matrix filling: an known error (displacement) is induced, and the difference image (to the correct image) is stored in the regression matrix. A linear relationship between displacement and correctional parameter is established. Later, during the search, the difference image directly relates to the ~~shift~~ necessary shift for perfect alignment.

-) CCA (Cannonical Correllation Analysis): The correllation between two signal spaces by neglecting low correllation components such as noise.

Active Appearance Models:

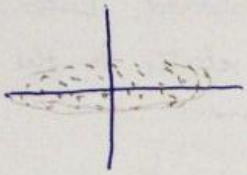
AAM's take into the account the shape AND the texture living within the shape. There are landmarks around and in the objects, connected in a way to form triangles. Each triangle contains a certain mean grey value. In training, they have to be normalized and ~~each~~ warped, so that all landmarks are in the same position and the grey value is updated. Training uses the methods above

ASM's (Active Shape Models):

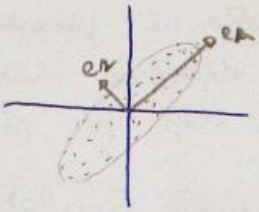
ASM's take only shape into account. The model search is an iterative fit between texture of the instance and model shape until best convergence is found. Here, the grey values along the ~~orto~~ orthogonal texture at each landmark are brought to ~~accord~~ alignment (finding minimal Mahalanobis distance)

4) fMRI measures the BOLD Signal = Blood Oxygen Level Dependend Signal.
The blood oxygen level of a brain region is indirectly related to the ~~amount~~ activity in this very region since it will consume more energy and hence needs more oxygen.
The normal MRI signal is measured, however ~~focussing on the~~ setting T_1 and T_2 so that the oxygen is best visible.
So the fMRI is a method to find neuronal activities.

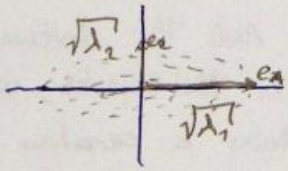
5) a) $A = \begin{pmatrix} 4 & 0 \\ 0 & 1 \end{pmatrix}$ (Covariance / Variance)



$B = \begin{pmatrix} 3 & 1 \\ 1 & 2 \end{pmatrix}$ (Covariance)



b) bei B macht eine PCA mehr Sinn, da die Covariantmatix $\neq 0$ ist.
Nach der PCA erhält man eine Darstellung, wo die Korrellationen entlang der Hauptachsen dargestellt sind (Dimensionalität wurde reduziert.)



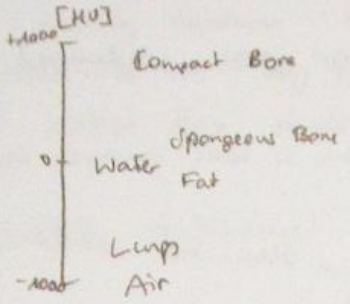
6) GLM is an univariant approach looking for correlation between a task and the BOLD signal at ONE position in the brain.
MVPA = also called "Brain reading" is a multivariant approach looking for correlation between ~~higher~~ a task and the BOLD-Signal at multiple places (= multiple pixels) in the brain.
So a MVPA also takes ~~the~~ higher order components processes (such as respiration or other potentially ~~the~~ appearing signals) into account.

In this example I would use the MVPA to get rid of potential "noise" and see the synchronisation between the regions → I need to map more regions so GLM wouldn't be sufficient.

7) a) Hounsfield Units

$$HU = 1000 \cdot \frac{\mu_{material} - \mu_{water}}{\mu_{water}}$$

μ ... Absorption coefficient

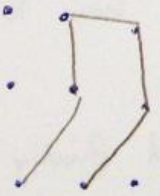


The characteristic measured in CT is the absorption of each tissue.

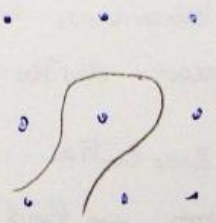
b) MRI. I do diffusion tensor imaging (DTI). The diffusion of water is biggest between vessels and nerves. Different gradients are applied to find the directions of diffusion. Then, every voxel is pictured with its diffusion tensor.

8) Snakes and Graph cuts both are <u>non-model-based</u> segmentation methods.

Snakes are ~~landmarked~~ segment <u>along</u> the pixels / voxels whereas graph cuts cut <u>between</u> them.



Snakes



graph cuts

They are limited in resolution and topology

continuous function

9) a) The joint probability distribution describes the probability of a pixel having value a in ~~Picture~~ Image X and value b in Image Y.

The smaller the "cloud" in the descriptive histogram (or parzen windowing), the better aligned they are!

Example of same modality:

The JPD is a similarity measure useful also in multi-modality registration.

b) .) Deformation: non-rigid (= affine + Free Form Deformation or ~~not~~ Thin Plate Splines)

affine: $Y = A \cdot x + B$

Translation, Rotation, Shear — Shift

Since different modalities have different geometric imaging behaviours, we might have to make up for non-linear distortion

.) Optimisation: Multi-Resolution (to avoid finding the wrong "local" maximum → find global maximum instead!)

.) Similarity: .) Could be <u>geometrical feature-based</u> (<u>gradient correlation</u>, extracting the high gradient features of whatever modality) or

.) <u>voxel feature based</u>

.) <u>JPD</u> (see question 9)a))

.) <u>Joint entropy</u> (the better aligned, the smaller joint entropy - sum of single entropies)

183 269

10) MEG = magnetoencephalogram / graphy

It directly measures brain activity = neuronal activity. The signals emitted are very small and the device has to be perfectly shielded to detect those small fields. It is an special form of MRI, however, no high frequency field is induced. Only the PRESENT signal is measured non-invasively!

Zeitliche Auflösung: MEG ~ msec ([redacted])

fMRI ~ 1 sec ([redacted] due to relaxation time)

Räumliche Auflösung: fMRI ~ 4mm } roughly the same
MEG ~ 5mm }