Questions and Answers

Chapter 3

Questions

(Q1) *What is the major purpose of image segmentation? Why is it so important in medical image analysis? Give some of its applications in medical science.*

(Q2) *Identify the major classes of techniques for image segmentation.*

(Q3) *Briefly describe the advantages and disadvantages of using edge detection techniques for image segmentation.*

(Q4) *What are the major drawbacks of using similarity mapping for functional image segmentation?*

(Q5) *What are the major differences between PCA and FA? Also, give some attributes that are in common in both methods.*

(Q6) *What are the major advantages of cluster analysis over other multivariate analysis approaches such as PCA and FADS?*

(Q7) *What are the major advantages of using clustering for characterizing tissue kinetics?*

(Q8) *What are the advantages and disadvantages of using manual ROI delineation with respect to using a template?*

Answers

(A1) Image segmentation is one of the essential preliminary steps leading to image understanding, visualization, analysis, and interpretation. The principal goal of image segmentation is to partition an image into regions that are homogeneous with respect to one or more characteristics or features under certain criteria. Each of the regions can be separately processed for information extraction. The most obvious application of segmentation in medical imaging is anatomical localization whose main aim is to outline anatomic structures and pathologic regions that are "of interest". Image segmentation is not only important for feature/information extraction and data visualization but also for image measurements and compression. It has found widespread applications in medical science, for example, localization of tumors and microcalcifications, delineation of blood cells, surgical planning, atlas matching, image registration, tissue classification, and tumor volume estimation and so on.

(A2) In general, segmentation techniques can be divided into four major classes:

- Thresholding
- Edge-based segmentation
- Region-based segmentation
- Pixel classification

These techniques are commonly employed in two-dimensional image segmentation in digital image processing community. More advanced techniques for multi-dimensional or multi-spectral image segmentation include:

- Model-based approach
- Multimodal approach
- Multivariate approach

(A3) The advantages of using edge detection techniques are that they are computationally fast and do not require any *a priori* information about the image. Numerous masks have been proposed over the years. However, selection of an appropriate mask is not a trivial task, and several attempts by means of trial-and-error maybe required to assess the performance of the masks on a specific application. Owing to measurement noise and acquisition artifacts (e.g. poor sampling), it is not uncommon that the edge pixels obtained with the selected mask do not characterize an edge and that the edges do not enclose the region completely. Post-processing by edge tracking/linking techniques such as graph searching and dynamic programming are often required to trace and link relating edge pixels to form meaningful edges or closed regions in the edge image.

(A4) The major drawbacks of this approach are:

- each similarity map only shows regions that are highly correlated with the reference region,
- the reference ROIs have to be defined manually, and
- spatial correlation between neighboring pixels does not take into account and thereby, the segmented region may be sparsely distributed and disconnected.

(A5) Major differences:

- PCA is a distribution-free method whereas FA assumes a statistical (Gaussian) model for the measurements.
- PCA cannot distinguish signal and noise because there is no assumption about the statistical properties for the measured data.
- PCA produces orthogonal components that are not physiologically meaningful (thus, difficult to interpret), whereas FA produces factors that are not necessarily orthogonal but physiologically meaningful (theoretically) upon rotation of factors.
- FA does not produce unique factors, whereas PCA produces PCs which are "almost" unique (because the components are not invariant under linear transformations of the variables).

Common:

- Both methods try to decompose the observed data in terms of a set of basis functions called principal components or factors.
- The extracted components/factors are assumed to be uncorrelated, which also implies independence for data with Gaussian distribution.

- Both methods provide nothing useful if the observed variables are nearly uncorrelated, because it has nothing to explain for FA, whereas the revealed principal components are close to the original variables for PCA.

(A6) Cluster analysis identifies the characteristic curves in the same space as the original data. This has advantages over PCA in terms of interpretation of identified principal components, and over FADS where the factor components are rotated, leading to possibly nonunique factor explanation and interpretation.

(A7) Functional imaging is good at characterizing tissue kinetics and kinetic modeling plays a crucial role in this regard. The aim of modeling is to interpret kinetic data quantitatively in terms of physiological and pharmacological parameters of a mathematical model, which describes the exchanges of radiotracer in the tissue. Statistical inferences can then be made regarding the distribution and circulation of tracers within different tissues regions which are quantitatively represented by the physiological/pharmacological parameters in the model. Successful statistical inference relies heavily on the appropriate use of analysis approaches and *a priori* knowledge of the underlying system, as well as the validity of the assumptions being made. Data-driven approaches such as cluster analysis can provide important clues to what is going on inside the underlying system and how the radiotracer behaves within the tissue, as they interrogate the measured data to characterize the complex processes, with minimal assumptions and independent of any kinetic model.

(A8) Although manual delineation of ROI can be labor-intensive and time-consuming and also has the potential for introducing intra- and inter-operator biases, it has advantages over the other approaches of using a standard template for ROI delineation/segmentation. While a template may attempt to describe a given anatomical region set in a more compact and complete manner (because it is a kind of model), inappropriate or unsuitable nonlinear transformations to "best" fit the anatomy could produce significant positional and geometrical errors for certain regions. This is a serious problem for analyzing brain data obtained from patients with severe anatomical variability caused by cerebral atrophy, infarction, trauma, and tumors, in particular, and in some cases caused by surgical operations or therapeutic treatment. In contrast, human operators can make use of model-based knowledge such as anatomical skills by mapping the anatomic/pathologic region to an atlas or template, and their cognitive abilities to define an appropriate spatial orientation for the dataset.