Mestrado em Engenharia Elétrica

Processamento de Imagem

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1. **Objetivo:** Pesquisar técnicas heurísticas para segmentação de imagens. Aplicações em processamento de imagens compreendendo:
   a. Lógica Fuzzy e Agrupamento
   b. Redes neurais
   c. Heurísticas de busca
   d. Aplicações
2. **Bibliografia:**
   a. The Image Processing Handbook – John Russ. IEEE Press
   b. Artigos diversos
3. **Metodologia**: aulas expositivas e trabalhos de implementação

A Survey of Current Methods in Medical Image Segmentation

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Introduction

- Diagnostic imaging is an invaluable tool in medicine today.
- Magnetic resonance imaging (MRI), computed tomography (CT), digital mammography, and other imaging modalities provide an effective means for non-invasively mapping the anatomy of a subject.
- These technologies have greatly increased knowledge of normal and diseased anatomy for medical research and are a critical component in diagnosis and treatment planning.
- With the increasing size and number of medical images, the use of computers in facilitating their processing and analysis has become necessary
- In particular, computer algorithms for the delineation of anatomical structures and other regions of interest are a key component in assisting and automating specific radiological tasks.
- These algorithms, called *image segmentation* algorithms, play a vital role in numerous biomedical imaging applications such as:
    - the quantification of tissue volumes,
    - diagnosis,
    - localization of pathology,
    - study of anatomical structure,
    - treatment planning,
    - partial volume correction of functional imaging data, and
    - computer integrated surgery.

- Methods for performing segmentations vary widely depending on:
    - the specific application,
    - imaging modality, and
    - other factors.
- General imaging artifacts such as noise, partial volume effects, and motion can also have significant consequences on the performance of segmentation algorithms.
- Each imaging modality has its own idiosyncrasies with which to contend.
- There is currently no single segmentation method that yields acceptable results for every medical image.
- Methods more general can be applied to a variety of data.
- However, methods that are specialized to particular applications can often achieve better performance by taking into account prior knowledge.
- Selection of an appropriate approach to a segmentation problem can therefore be a difficult dilemma.

Background

- Classically, image segmentation is defined as the partitioning of an image into non-overlapping, constituent regions which are homogeneous with respect to some characteristic such as intensity or texture.

- If the domain of the image is given by *I*, then the segmentation problem is to determine the sets $S_k \subseteq I$ whose union is the entire image *I*. Thus, the sets that make up a segmentation must satisfy:

$$I = \bigcup_{k=1}^{K} S_k \qquad S_k \bigcap S_j = \emptyset \text{ for } k \neq j,$$

- When the constraint that regions be connected is removed, then determining the sets S_k is called *pixel classfication* and the sets themselves are called *classes*.

- Pixel classification rather than classical segmentation is often a desirable goal in medical images, particularly when disconnected regions belonging to the same tissue class need to be identified.

- Determination of the total number of classes K in pixel classification can be a difficult problem.

- Often, the value of K is assumed to be known based on prior knowledge of the anatomy being considered.

- *Labeling* is the process of assigning a meaningful designation to each region or class and can be performed separately from segmentation.

- It maps the numerical index k of set S_k, to an anatomical designation.

- In medical imaging, the labels are often visually obvious and can be determined upon inspection by a physician or technician.

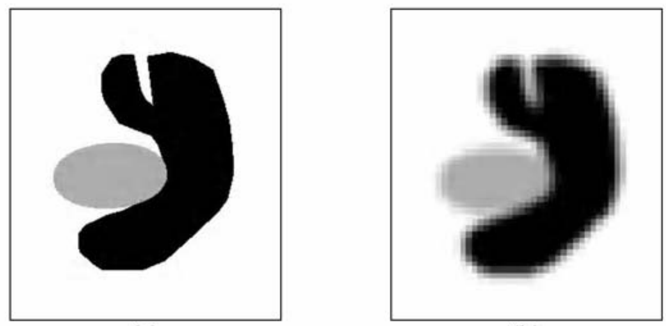
- Computer automated labeling is desirable when labels are not obvious and in automated processing systems.
- A typical situation involving labeling occurs in digital mammography where the image is segmented into distinct regions and the regions are subsequently labeled as being healthy tissue or tumorous.
- Motion estimation methods often consist of applying segmentation algorithms to time sequences of images.
- The distinction we make between segmentation and feature detection is that feature detection is concerned with determining the presence of some image property while segmentation generally assumes that the property is already present and attempts to precisely localize areas that possess the property.
- For example, edge detection methods can determine the location of edges in an image but without further processing, do not necessarily extract any region of interest.

Dimensionality

- Dimensionality refers to whether a segmentation method operates in a 2-D image domain or a 3-D image one.
- Methods that rely solely on image intensities are independent of the image domain.
- However, certain methods such as deformable models, Markov random fields, and region growing incorporate spatial information and they may therefore operate differently depending on the dimensionality of the image.
- Generally, 2-D methods are applied to 2-D images and 3-D methods are applied to 3-D images.
- In some cases, however, 2-D methods are applied sequentially to the slices of a 3-D image.
- This may arise because of practical reasons such as ease of implementation, lower computational complexity, and reduced memory requirements.
- In addition, certain structures are more easily defined along 2-D slices.
- A unique situation that occurs in medical image segmentation is the delineation of regions on a non-Euclidean domain such as in brain cortex parcellation.
- This is essentially segmentation on a *surface* of measurements, because a surface is a 2-D object folded in 3-D space, segmentation on a surface can not be treated as a standard 2-D or 3-D problem.

Soft segmentation and partial volume effects

- Segmentations that allow regions or classes to overlap are called *soft segmentations,* important in medical imaging where multiple tissues contribute to a single pixel or voxel resulting in a blurring of intensity across boundaries.
- Figure 1 illustrates how the sampling process can result in partial volume effects, leading to ambiguities in structural definitions.



(a) (b)

- In Figure 1b, it is difficult to precisely determine the boundaries of the two objects.

- A *hard segmentation* forces a decision of whether a pixel is inside or outside the object.
- Soft segmentations on the other hand, retain more information from the original image by allowing for uncertainty in the location of object boundaries.

- In pixel classification methods, the notion of a soft segmentation stems from the generalization of a set *characteristic function* that is simply an indicator function of where a pixel is inside or outside its corresponding set.

$$0 \leq m_k(j) \leq 1, \text{ for all } k, j$$

$$\sum_{k=1}^{K} m_k(j) = 1, \text{ for all } j$$

The value of a membership function $m_k(j)$ can be interpreted as the contribution of class k to location j.

Wherever membership values are greater than zero for two or more classes, those classes are overlapping.

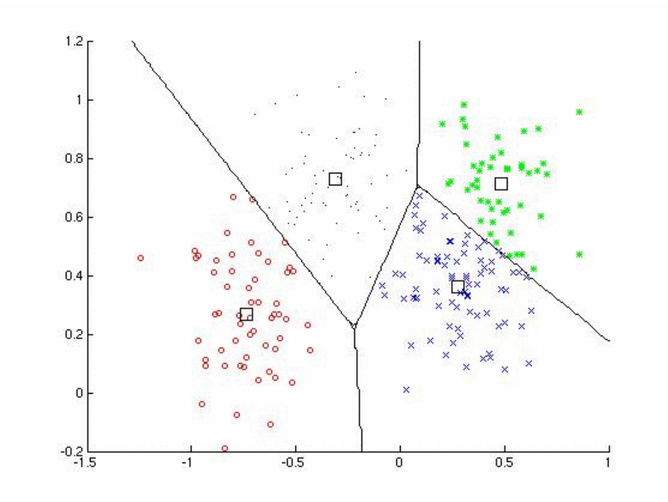
If the membership function is unity for some value of j and k, then class k is the only contributing class at location j.

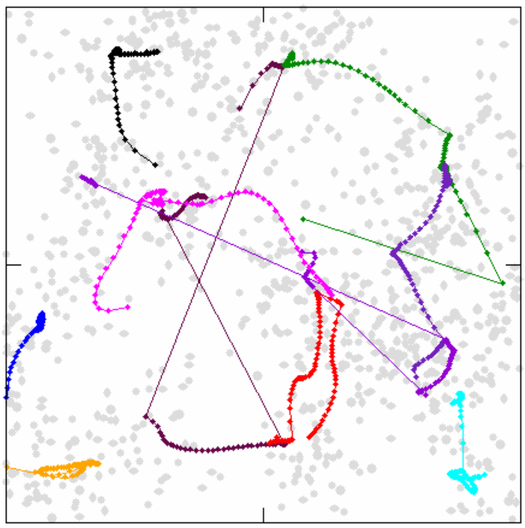
- Membership functions can be derived using fuzzy clustering and classifier algorithms, statistical algorithms in which case the membership functions are probability functions, or they can be computed as estimates of partial volume fractions.

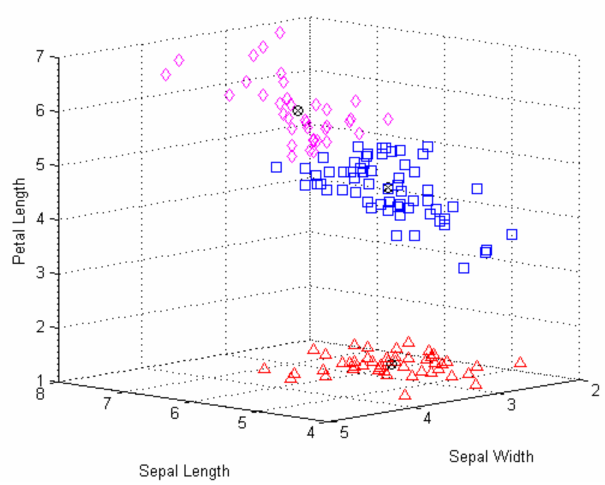
Clustering

- Clustering algorithms essentially perform the same function as classifier methods without the use of training data, being termed *unsupervised* methods.
- In order to compensate for the lack of training data, clustering methods iterate between segmenting the image and characterizing the properties of the each class, training themselves using the available data.
- Three commonly used clustering algorithms are:
    - K-means or ISODATA algorithm,
    - Expectation-maximization (EM) algorithm.
    - Fuzzy c-means algorithm,
- Although clustering algorithms do not require training data, they do require an initial segmentation (or equivalently, initial parameters).
- Like classifier methods, clustering algorithms do not directly incorporate spatial modeling and can therefore be sensitive to noise and intensity in homogeneities.
- This lack of spatial modeling, however, can provide significant advantages for fast computation.

- **The K-means** clustering algorithm clusters data by iteratively computing a mean intensity for each class and segmenting the image by classifying each pixel in the class with the closest mean.







- **The EM algorithm** applies the same clustering principles with the underlying assumption that the data follows a Gaussian mixture model.
- It iterates between computing the posterior probabilities and computing maximum likelihood estimates of the means, covariances, and mixing coefficients of the mixture model.
- The EM algorithm has demonstrated greater sensitivity to initialization than the K-means or fuzzy c-means algorithms.