Development of an expert system for unsupervised segmentation of MRI

Mahmood Mayanloo, étudiant 3e cycle

Dr Hue Tue Huynh, directeur de recherche

Abstract: Our goal is to produce a system that automatically segments and labels normal and abnormal tissues in magnetic resonance images of the human brain. The magnetic resonance images consist of three feature images (T1, T2 and PD) and are treated by a system which integrates knowledge-based techniques with multispectral analysis. Initial segmentation is performed by the Tree-Structure Self Organizing Map, an unsupervised artificial neural network clustering algorithm. The segmented image, along with cluster centers for each class is then provided to a rule-based expert system which carries out the final stage to extract and to label the segmented tissue regions.

Résumé: Notre but est de produire un système qui segmente et étiquette automatiquement les tissus normaux et anormaux dans des images de résonance magnétique du cerveau humain. Les images de résonance magnétique se composent de trois images (T1, T2 et PD) et sont traitées par un système qui intègre des techniques basées sur la connaissance avec l'analyse multispectrale. La segmentation initiale est exécutée par la méthode du Tree-Structure Self Organizing Map, un algorithme groupant de réseau neurologique artificiels. L'image segmentée, avec les centres groupants pour chaque classe est alors fournie à un système expert qui exécutent l'étape finale d'extraire et d'étiqueter des régions de tissu segmentées de tissu.

Magnetic Resonance Imaging has become a widely used method of high quality medical imaging. This is especially true for brain imaging where MRI's soft tissue contrast and non-invasiveness are clear advantages. MRI has a unique advantage over other modalities, such as Computer Tomography, CT, and Positron Emission Tomography, PET, in that it can provide images of tissues with a variety of contrasts based on a simple adjustment of parameters, which define the experiment, figure 1 . In a sense the images obtained from MRI resemble the multi-band or multispecral images of the earth obtained from the remote sensing satellites. Multidimensional data classification has been used extensively in the area of remote sensing and comparison between multi spectral images of the earth and MRI was made as early as 1985 [1].

Segmentation of MR images is an important step in the visualization and recognition of soft tissues and organs in the body. Multi spectral approaches have the advantage of using a large set of information compared with that obtained with single contrast techniques [2]. The relative pixel intensities in the multispectral data set for each tissue class result in the formation of related tissue clusters in feature space. Pattern recognition is the most common approach in multispectral MR image data sets of finding rules that allow a mapping of pixel intensity value onto different tissue types. The analysis of such multicontrast images can be achieved by using parametric or non parametric supervised or unsupervised methods. Supervised segmentation requires training data sets for identify each tissue type. The stability of these methods depends on the accuracy of locating a region of interest, ROI, within the same image slice, adjacent slice or slices from a different imaging session for training [3]. Many pattern recognition methods assume particular distributions of the features, and are called parametric methods . Parametric methods are only useful and valid for MR images when the feature distributions for different classes are well known [4]. Maximum likelihood is a representative for the parametric methods where the algorithm first uses the training samples to calculate the mean vector and the covariance matrix and where for each pixel the probability for membership of each class is then calculated; finally a decision is made for classification of each pixel, and the class of highest probability is chosen.

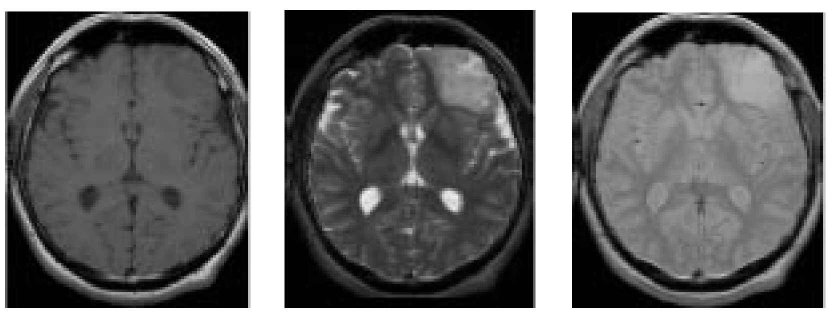

Figure 1 *a) T1 weighted image b) T2 weighted image c) PD weighted image*

Non parametric methods, are divided into two main categories, statistical and non statistical. K-Nearest Neighbors, k-NN, is an exemple from the family of non-parametric statistical methods that does not use any particular distribution, but estimates a posterior probability from the distribution of neighbors in feature space. Finally the artificial neural network technique, ANN, is a non statistical method which is an attractive solution to a number of pattern recognition problems [5] . Its major advantage is that it does not rely on any assumption about the underlying probability density functions, thus possibly improving the results when the data significantly depart from normality. Using the clustering techniques which automatically determine the structure in the data is a very promising solution for the segmentation of medical images. In fact, it was found that unsupervised clustering shows good results for tumor volume determination. The initializing of these methodsplays a very important role in minimizing the computing time burden [6].

The goals of this project will be to produce an automated segmentation method in which image features (such as for a head image: skin, fat, CSF, white matter and gray matter) would be separated into individual 2D data sets so that they can be displayed, in different colors, either separately or in different combinations. Also, once the segmentation has been achieved, the individual data sets should be used for measuring the total volume and overall dimensions of each feature, and for calculating MR relaxation times for each feature.

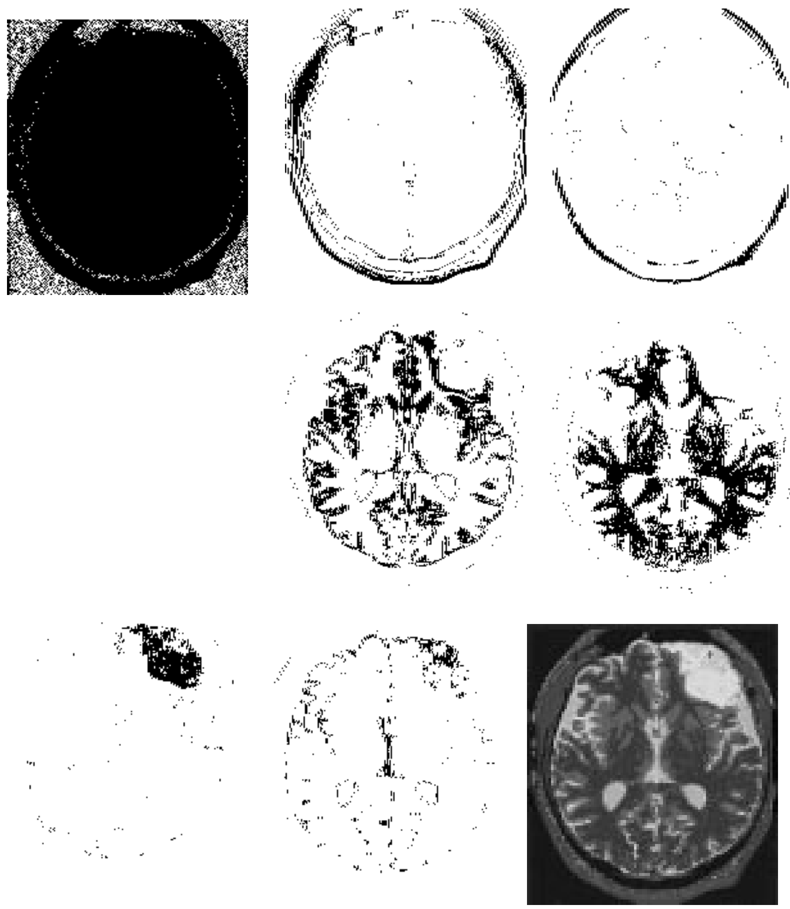

Figure 2 Initial segmentation of an abnormal brain MRI data set by TS-SOM algorithm

The approach used to construct the proposed segmentation algorithm is based on a tree-structured self-organizing map (TS-SOM) [7] neural network. Multispectral segmentation of the MR image data is carried out by applying the TS-SOM method to a set of data composed of several images, which are obtained at the same slice location. These images are obtained with various degrees of Repetition Time, TR, and Echo Time, TE, weighting in order to differentiate tissues with different T1, T2 and proton densities. Finally a rule-based expert system is developed to control the whole segmentation process in order to recognize normal and abnormal tissues and assign each segmented region corresponding to its morphological characteristics. Figure 2 demonstrates segmented clusters of the TS-SOM algorithm applied to the three images of figure one. These images are labeled in a supervised manner. Once the expert system is ready to operate these tasks will be done in an unsupervised way.

References

[1] M. W. Vannier, R. L. Butterfield, D. L. Rickman, D. M. Jordan, W. A. Murphy, R. G. Levitt, and G. Mohktar, ‘‘Multispectral analysis of magnetic resonance images’’, Radiology, Vol. 154, no 1, pp. 221-224, 1985.

[2] B. Alfano, A. Brunetti, M. C. Eugenio, M. Quarantelli, M. R. Panico, A. Ciarmiello, M. Salvatore, “Unsupervised, Automated Segmentation of the Normal Brain Using a Multispectral Relaxometric Magnetic Resonance Approach”, JMRI 1997.

[3] L. P. Clatke, R. P. Velthuizen, M. A. Camacho, J. J. Heine, M. Vaidyanathan, L. O. Hall, R. W.Thatcher, M. L. Silbiger, “MRI Segmentation: Methods and Applications" , Magnetic Resonance Imaging”, Vol. 13, No. 3, pp. 343-368, 1995.

[4] L. P. Clarke, R. P. Velthuizen, S. Phuphanich, J. D. Schellenberg, J. A. Arrington, M. Silbiger, “MRI: Stability of Three Supervised Segmentation Techniques”, MRI, Vol. 11, pp. 95-106, 1993.

[5] M. Ozkan, B. M. Dawant, R. J. Maciunas, “Neural Network-Based Segmentation of Multi-Modal Medical Images: A Comparative and Prospective Study”,Transactions on Medical Imaging, Vol. 12, No. 3, Sept. 1993.

[6] A. Simmon, S. R. Arridge, G. J. Barker, S. C.R. Williams, “Simulation of MRI Cluster Plots and Application to Neurological Segmentation”, MRI, Vol. 14, no. 1, pp. 73-92, 1996.

[7] P. Koikkalainen, “Fast deterministic self-organizing maps”, ICANN95, pp. 63-68, 1995.