3-D Image Classification: A Study Using Functional MRI Data

Can we develop appropriate 3-D classification techniques that incorporate spatial relationship information while at the same time achieving effective performance given the significant size of 3-D data sets?

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1. Background and Research Overview

Data mining is concerned with the discovery of hidden knowledge in data. Early work concentrated on tabular data, and the knowledge was defined as anything that could not be extracted by simple querying. Subsequent work has been directed at much wider data formats, examples include: free text, video, graphs and images. Image mining can be identified as a current sub-field of research in its own right. The predominant research issue in image mining is how to represent images so as to facilitate data mining. Usually this involves some sort of segmentation, registration and/or enhancement activity, followed by the encoding of images into an appropriate format.

Image mining is usually conducted in the context of 2-D images, for example categorising WWW images or the contents of 'photo banks. The application of data mining techniques to 3D images has received very little attention. A practical example of where such images are generated is in Magnetic Resonance Imaging (MRI) brain scan data where sequences of images are taken, each representing a "slice" of the brain. The sequences are generated vertically or horizontally. Collectively, a sequence of slices is called a volume. A volume can therefore be conceptualised as a 3-D image.

The aim of the proposed research is to investigate mechanisms where by data mining techniques, specifically classification techniques, can be applied to 3-D images such as MRI scan volumes. There are a number of significant research issues to be addressed:

1. **3-D Spatial Relationships.** For many image mining applications, although not all, the spatial relationship between individual pixels or groups of pixels (segments) is significant. It is therefore desirable to maintain this information with respect to classification. Some work has been conducted at Liverpool, in the context of 2-D image features, to maintain spatial information. How spatial information can be retained in 3-D images remains an open question.
2. **The Volume of Data.** The volume of data, at the pixel level, in 2-D data sets is significant. The volume of data in 3-D images, at the voxel level, thus presents an even greater challenge. One solution is to "coarsen" the image resolution, this will involve the loss of data and will reduce the classification accuracy. An alternative is to focus in on certain parts of the image which are significant with respect to the desired classification (the remainder of the image data can then be safely ignored). The question is how do identify these sub-volumes.
3. **Representation**. Given the above considerations the nature of the desired data structure to be used is unclear. Clearly the representation should be compatible with classification techniques. However, given the number of voxels in a volume, any adopted/developed data structure should be computationally viable. At the same time the representation should be able to incorporate spatial information.

The propose work would strive to address the above issues. The overall research question would be directed at generic 3-D image classification, "Can we develop appropriate 3-D classification techniques that incorporate spatial relationship information while at the same time achieving effective performance given the significant size of 3-D data sets". Three specific research goals would be addressed:

1. How can spatial relationships be incorporated into 3-D image data in such a way that they can be effectively utilised by classification algorithms?
2. Is it possible to enhance the efficiency and/or effectiveness of 3-D image classification by identifying sub-volumes within volumes that are likely to be most significant with respect to classification?
3. How does the coarsening of 3-D images, to enhance computational efficiency, effect classification accuracy?

2. Application Domain

To act as a focus for the research, and to provide a specific evaluation platform, the research will be directed at classification of functional MRI (FMRI) data. Magnetic Resonance Imaging (MRI) is a technique used in radiology, typically in the context of medical applications, to provide visualisations of the internal organs and tissues. FMRI is a special form of MRI that can be used to measure changing neural activity in the brain resulting from external stimuli. Neuroscience research using FMRI, conducted within MARIARC (The Magnetic Resonance and Inage Analysis Research Center at the University of Liverpool), has focused on identifying the parts of the brain that are active in response to external stimuli such as different colours and lines orientated at different angles. Standard analysis considers each voxel in isolation and uses simple regression to determine whether the external stimulus produces any variance in the MRI time course. Thus identifying the area of the brain activated by external stimuli. A new approach considers instead the classification of patterns of brain activity, i.e. combining information across voxels. Some domain specific issues that are a feature of FMRI, and that relate to the above research goals, are as follows:

1. Each voxel (volumetric pixel) in an FMRI volume represents a 2mm cube and thus represents a substantial portion of the brain, there may therefore be little scope for coarsening images to enhance computational efficiency. There is a suspicion that the resolution of current FMRI volumes is not always sufficient to allow classification. This depends very much on the nature of the external stimulus, and the network of brain areas that may be involved.
2. There are examples where FMRI collections have produced reasonable classification results (better than a guess), however there are also many examples where results have been poor.
3. It is conjectured that for some FMRI classification scenarios the spatial relationship between voxels is significant. Current work on FMRI has not addressed this issue.
4. To enhance classification efficiency of FMRI volumes, the classification is typically directed at hand selected sub-volumes. The question is, can these sub-volumes be identified automatically by a preliminary classification process?
5. Not withstanding (1) above, to enhance the computational efficiency a degree of coarsening may be appropriate, however it is unclear what affect this has on accuracy. An investigation of the nature of the reduction in accuracy as FMRI volumes are progressively coarsened is therefore seen as desirable.
6. In some cases, classification is believed to rely on sub-voxel clustering of responsive neurons. It may be possible to infer the size of these clusters by altering the voxel size.

3. Research Team

The proposed research would be supervised jointly by members of staff with the Department of Computer Science and psychology at the University of Liverpool, and the department of imaging sciences at the University of Manchester.

A number of imaging datasets are available for analysis.

4. Some Suggested Background Reading

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