

AUTOMATIC EXTRACTION OF HIGH TEXTURE FEATURES USED FOR  
PATIENT REALIGNMENT IN MEDICAL IMAGING OF THE HEAD

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ABSTRACT

In order to develop a technique for automatic patient realignment in medical imaging particularly in magnetic resonance imaging (MRI) of the brain it is essential to extract key features automatically from the various slices of the head with as great an accuracy as possible.

The brain is a key feature which is vital for the accurate realignment of the patient in all the 3 planes (Sagittal, Transverse, Coronal).

The MRI scans (T1 spin-lattice relaxation time) which produce fast images and are therefore used in patient realignment, provide highly textured images. These are difficult to segment using conventional thresholding or edge enhancement techniques due to their "grainy" appearance, making it difficult to isolate the brain from the other components found in the slice.

In this paper a method is developed for the accurate extraction of the brain profile in the sagittal, transverse and coronal scans of the head by enhancing the original image to remove the high texture content. This results in a good working image which isolates the brain from other features, in a particular slice.

The results obtained by implementing the algorithm on scans, taken of the same patient over a period of time, show the very high accuracy of the brain extraction algorithm.

1. INTRODUCTION

In medical imaging for diagnostic purposes, it is essential to reposition

the patient during successive sets of scans, to the position acquired during the first set of scans (the master set), (Kingsley D.P.E, 1980). This means that a check can be kept on the growth of a disease. Slight misalignment can mean losing a considerable part of the region of interest (diseased area). Therefore, the realignment of the patient is crucial and is a prerequisite for any imaging technique (x-ray, MRI, PET etc).

In this paper magnetic resonance images (MRI) of the brain will be considered. Majority of the MRI scanners maintain a distance of 5mm between slices. Scanners capable of 3mm resolution between slices are now available. The goal laid down is that realignment of the patient should be achieved to within  $\pm 1$ mm in the 3 planes (sagittal, transverse, coronal). The MRI images are digitised to a spatial resolution of  $256 * 256$  pixels and a gray-level resolution of 12 bits. The images examined in this paper have been rescaled to have a resolution of 8 bits.

Realignment of the patient can be achieved by examining the dimensions of the key features extracted in the various scans taken over a period of time thus implying that these must be extracted very accurately. The brain is a key feature that is essential for realignment, particularly in the sagittal and the transverse scans.

In this paper a method is described to extract the high textured image of the brain very accurately. The accuracy of the method has been confirmed by superimposing the brain outline on the sagittal scan of the head. The method is fully automatic and does not require any arbitrary

thresholding, prior knowledge of the approximate slice position or of the key feature content in the slice.

## 2. PATIENT REALIGNMENT BY THE RADIOGRAPHER

Present patient realignment technique is wholly dependent on the expertise of the radiographer in repositioning the patient during successive scans (Alvey Project report I, 1986). During the first visit the patient is placed in the scanner in a position that he finds most comfortable and then scans are taken in the various planes. The resulting graylevel pictures are digitised and then stored on disks or magnetic tapes.

On successive visits, the patient is positioned by the radiographer so that slices in the various planes correspond to those taken on the first visit. Initially, the sagittal image of the patient in the current scan is compared with that obtained on the first visit. Using the knowledge gained over a period of time, the radiographer is able to estimate the new position of the patient so that there is realignment. To estimate movement requires the identification of the key features within the slices. Typically, in a sagittal scan these are the brain and the brain stem, and having identified this region, other key features within the brain (the corpus collosum, the pons etc) can be extracted (Alvey Project report II 1987).

## 3. AUTOMATIC REALIGNMENT OF THE PATIENT

A technique is being developed for the automatic realignment of patients in medical imaging. The technique is similar to that used by the radiographer in that key features that identify a slice are extracted using both well established, and new image processing techniques (Rosenfield A, 1987). Of prime importance is the brain in the

sagittal scan which contains features that are very "grainy" thus implying that the texture content in the image is high and as such it becomes difficult to isolate the key features from one another especially, isolation of the brain.

A technique has been developed to enhance the image thereby removing the texture and thus making it much easier to isolate the brain. A full description of the algorithm is given in the proceeding section.

## 4. BRAIN EXTRACTION ALGORITHM

Thresholding of the image in selective regions of the sagittal scan was first investigated (Rosenfield A, Kak A.C, 1982). This was a very slow and inaccurate process. Two or more regions merged to form a one large region thus giving erroneous results.

Established edge operators (Fau-geras O.D, 1983) were implemented on the sagittal images and it was found to be impossible to link the strong edges to produce a brain outline. Fig (3) shows the image obtained when a Sobel edge operator was run on the 'grainy' sagittal scan of fig (1). A considerable amount of prior knowledge was required about the feature content in the slice to join these edges to produce a feature that resembled the brain. This defeats the main objective which is to extract the brain without any prior knowledge of the feature content.

The first step in the brain extraction algorithm is the enhancement of the image to remove the texture. The second step involves the extraction of the brain outline in the enhanced scan. This contour is then filled in with gray pixels using a contour filling algorithm.

#### 4.1. Texture removal

A texture measure  $T(i,j)$  is defined as follows :-

$$T(i,j) = \frac{g_{\max} - g_{\min}}{g_{\text{mean}}} \quad (1)$$

where  $(i,j)$  is the position of the central pixel in a  $3 \times 3$  pixel window

$g_{\max}$  and  $g_{\min}$  are the maximum and minimum graylevels in the  $3 \times 3$  pixel window (centred on location  $i,j$ ) respectively.

$g_{\text{mean}}$  is the mean graylevel in the  $3 \times 3$  pixel window.

$T(i,j)$  is computed for all pixels in the image and from this the mean,  $T_m$  and the standard deviation,  $T_\sigma$  for the texture measure are computed i.e

$$T_m = \frac{\sum_{j=1}^{j_{\max}} \sum_{i=1}^{i_{\max}} \frac{g_{\max} - g_{\min}}{g_{\text{mean}}}}{j_{\max} * i_{\max}} \quad (2)$$

where  $i_{\max}$  and  $j_{\max}$  are the maximum number of lines and columns in the image, respectively.

A threshold measure  $T_h$  is defined to remove the texture from the image. This measure is a function of the mean and the standard deviation of the texture measure.

$$T_h = k * f(T_m, T_\sigma) \quad (3)$$

$$f(T_m, T_\sigma) = \left(1 + \frac{T_m}{T_\sigma}\right) \quad (4)$$

where  $k = 0.5$  is the constant of proportionality.

To remove the texture in the image,  $T(i,j)$  is again computed for all the pixels in the original image.

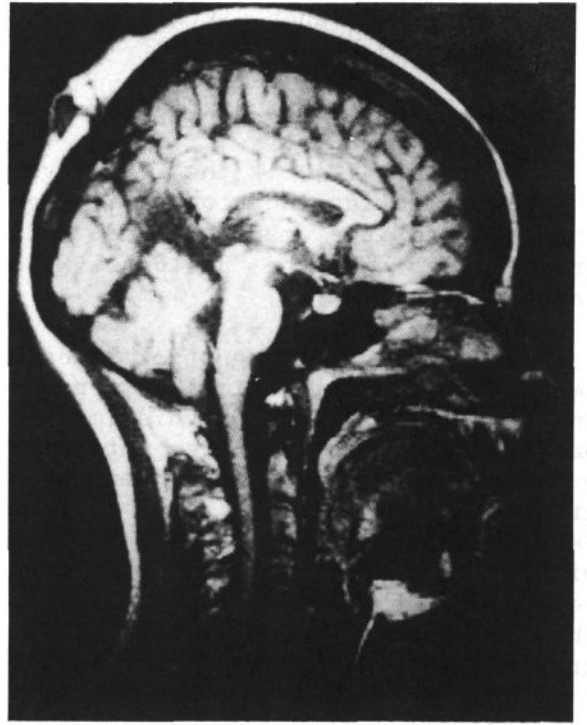


Fig 1 Magnetic resonance image (Sagittal view)

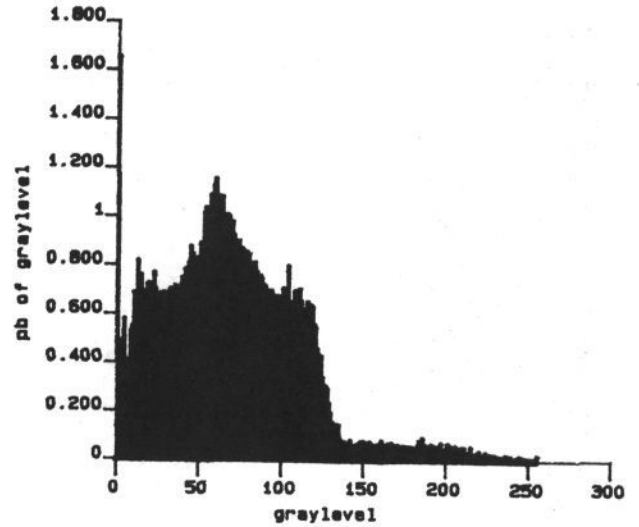


Fig 2 Graylevel Histogram of original "grainy" sagittal view

If  $T(i,j) < T_h$  then  $\text{pix}(i,j) = \text{gmax}$  (5)

If  $T(i,j) \geq T_h$  then  $\text{pix}(i,j) = \text{gmed}$  (6)

where  $\text{pix}(i,j)$  is the gray value of the pixel at location  $(i,j)$ .  $\text{gmax}$  and  $\text{gmed}$  are the maximum and median gray values in the  $3 \times 3$  pixel window respectively.

Fig(1) shows a magnetic resonance image (T1 relaxation time) of a patient in the sagittal plane. In this image the background pixels (i.e. area outside the outer skull boundary) have been set to graylevel 0. Fig(2) shows the gray-level histogram within the head i.e. within the outer skull boundary. The region of the brain is made up of both the higher and the lower graylevels. This meant that simple thresholding to extract the brain was not feasible.

Fig(4) shows the enhanced image of the head. There is a distinct spatial gray level distribution within the region of the brain. The resulting gray-level histogram is shown in fig(6).

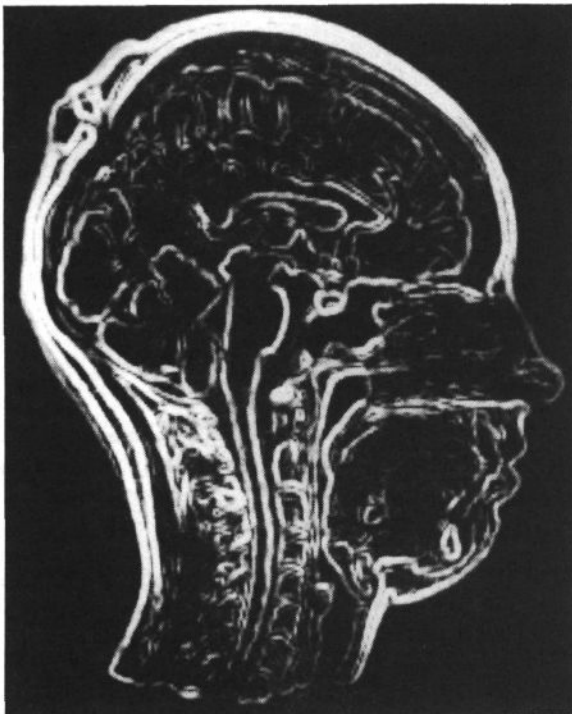


Fig 3 Edge Enhancement (Sobel operator)

#### 4.2. Contour following algorithm

On examining the graylevel histogram for the enhanced image it was found that the level that was most dominant in the histogram was that which occurred most in the region of the brain.

Thresholding of the enhanced image to produce a binary image of the brain gave inaccurate results. In addition, selection of the threshold value was a cumbersome task as too high a value fused the brain with other parts of the head whereas, too low a threshold gave an incomplete brain region. However, it was noted that in extracting the brain by thresholding the enhanced image produced a much better image of the brain than that obtained when the original "grainy" scan was thresholded.

Having examined the pitfalls of the thresholding technique a contour following algorithm (CFA) was implemented on the enhanced image (Pratt W.K, 1978). In this method, the CFA locks onto the dominant graylevel (initial level) and then tracks graylevels within  $\pm p\%$  of this initial value. It was found that a value of  $p$  of between 5% and 12% gave a good outline of the brain. The extracted brain boundary superimposed on the original sagittal scan is shown in fig(5).

Having extracted the region of the brain accurately various measurements (area, perimeter, centre of mass, 2nd order moments etc) were carried out on this feature. These are vital for the comparison of two extracted features of the same type and from the same patient obtained from scans taken on different occasions. There is perfect registration of the two images when the patient is perfectly realigned.

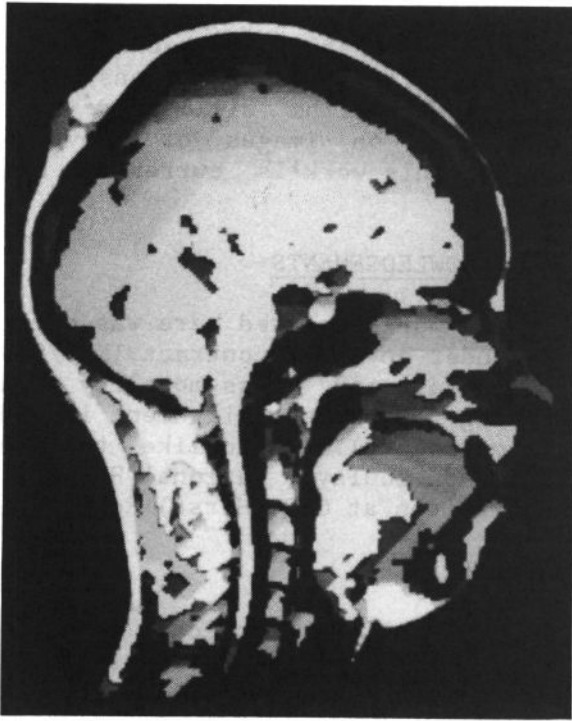


Fig 4 Enhanced sagittal image  
(texture removed)

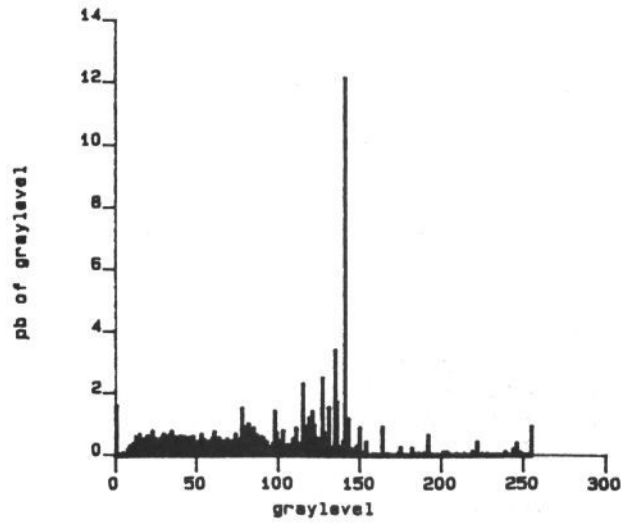


Fig 6 Graylevel Histogram of enhanced  
sagittal view

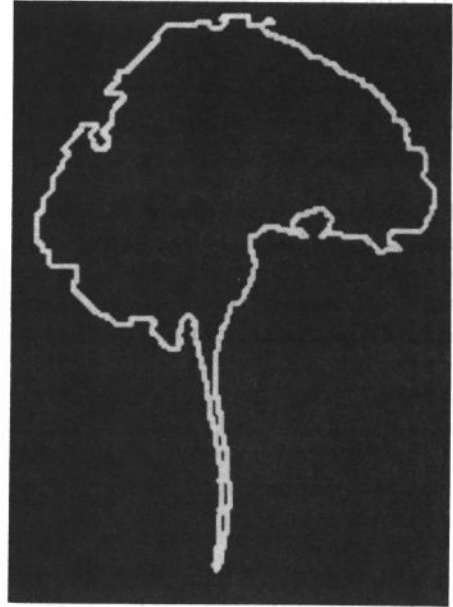


Fig 7 Brain contour



Fig 5 Extracted brain boundary  
superimposed on the  
original MRI scan

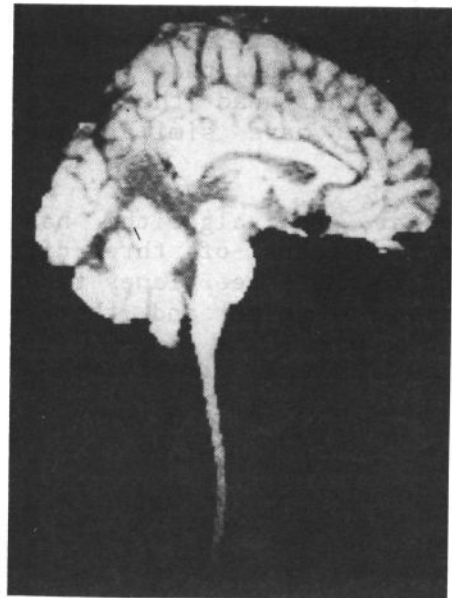


Fig 8 Isolated brain region

## 5. RESULTS

In addition to the isolation of the brain from other features in the sagittal scans, the brain extraction algorithm was applied to transverse and coronal scans of the head and the results confirmed the high accuracy of the algorithm.

Fig(8) shows the isolated brain after filling the region within the brain contour (fig 7) with the corresponding gray pixels obtained from the "grainy" image.

## 6. CONCLUSION

From the results shown, the accuracy of the brain extraction algorithm has been established. The method is fast as it requires only two passes of the image and on each occasion only a 3\*3 pixel window is examined for each pixel in the image.

The implementation of edge detectors on the original "grainy" scan was considered to be unsuitable due to the numerous edges found in MRI scans of the head. Discriminating between the edges around the region of the brain and those within the brain is not only time consuming but virtually impossible to achieve without prior knowledge of the feature contents within the slice in question.

In the case of the MRI scans examined so far, the number of computations of the median value for 3\*3 pixel window was less in number than the computation of the maximum gray value in the windows. This meant a lower processing time. This also shows that for the MRI scans of the head there are many regions that have similar graylevel distribution.

So far, the algorithm has been applied to scans of three different patients in the three planes taken over a period of time and the results

obtained have been consistent with those indicated in this paper. However, to confirm that this technique is universal for all MRI scans of the head, the algorithm will need to be implemented on images of many more patients. This work is currently being conducted.

## 7. ACKNOWLEDGEMENTS

The work reported here was carried out under an ALVEY contract, IKBS/053 ( " Temporal and cross-modality image matching for patient alignment in medical imaging " ). I would like to thank Prof. G du Boulay ( National Hospital ) and B Dalton at GEC (Hirst) Research.

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