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Hierarchical Clustering-based Segmentation (HCS) Aided Interpretation of Multi-parametric MR Images of the Prostate

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BACKGROUND

Tissue abnormality is usually related to a dissimilar part of an otherwise homogeneous image. Choosing the optimal post processing threshold value can be difficult because the image composition may vary depending on the acquisition parameters and the type of tissue. Hierarchical Clustering-based Segmentation (HCS) is an approach to Computer Aided Monitoring (CAM) that enables a user to define a region of interest and the process generates a hierarchy of segmentation results to highlight the varied dissimilarities that might be present.

HCS allows the user to derive the maximum benefit from the computational capability (perception) of the machine while at the same time, enabling them to incorporate their own interpretation in the appropriate place. This achieves a complementary synthesis of both computer and human strengths [1].

Aim of the Study - HCS PROCESS AS AN AID TO DIAGNOSIS IN mpMRI OF PROSTATE

To evaluate HCS process as semi-quantitative analytical tool, to complement radiologist's interpretation of mpMR images of prostate

Hierarchical Clustering-based Segmentation (HCS)

Hierarchical Clustering-based Segmentation implements the traditional bottom-up approach of agglomerative clustering, where the regions of an initial partition are iteratively merged. Thus HCS automatically generates a hierarchy of segmented images.

A unique operation of the HCS process is the border pixel reclassification. Border pixel reclassification aides in overriding local inhomogeneity while clustering similar regions (Figure 1). The algorithmic diagram below, illustrates the overall operation of the HCS process [2].

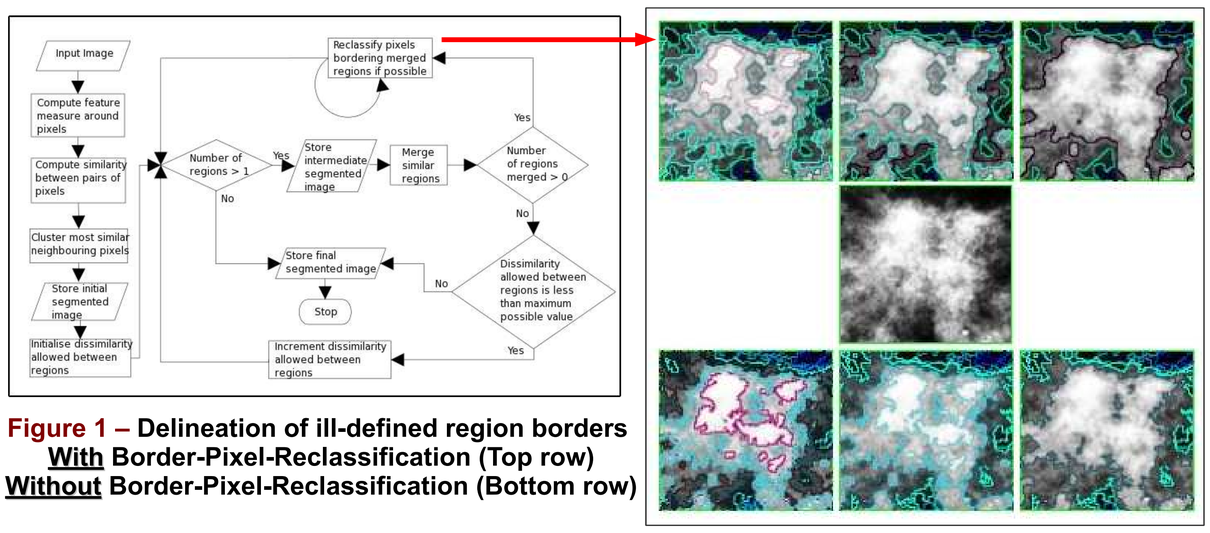


Figure 1 – Delineation of ill-defined region borders
With Border-Pixel-Reclassification (Top row)
Without Border-Pixel-Reclassification (Bottom row)

METHOD

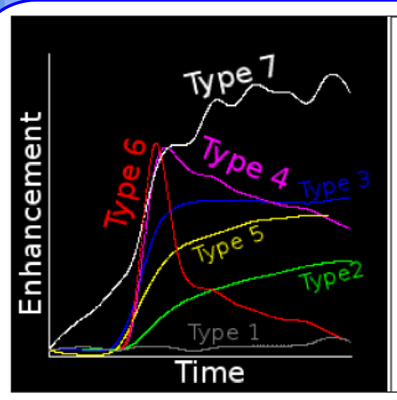
In prostate cancer, the leaky characteristics of the tumour angiogenesis, is demonstrated in DCE-MRI by the early rapid high enhancement just after the administration of contrast medium followed immediately by a relatively rapid decline. In comparison there will be a lower and continuously increasing enhancement for normal tissues.

The above characteristics can be demonstrated by the quantitative measurement of signal enhancement in DCE-MRI with time *i.e.* Time Intensity Curve (TIC). The characteristic shape of the TIC (Figure 2) may be used for supporting diagnosis.

Within the user defined ROI, the HCS process is applied to the DCE-MRI temporal frame of a slice of interest identified by the user.

For qualitative analysis, for dissimilar regions, HCS process provides following (Fig. 3A, B) heat map, regions coloured as per their TIC types and correlation with T2 regions.

For quantitative analysis, parametric image of the time intensity curves of the contrast wash-in, wash-out process are plotted for suspicious regions confirmed by user (Fig. 3C).



Type 1 (Gray) : No enhancement; (Benign).
Type 2 (Green) : Slow enhancement, maximum reached after half scan; (Benign).
Type 3 (Blue) : Quick enhancement, followed by signal plateau; (Carcinoma).
Type 4 (Magenta) : Fast enhancement and quick washout; (Carcinoma).
Type 5 (Yellow) : Quick enhancement, followed by constant enhancement; (Benign).
Type 6 (Red) : Artery.
Type 7 (White) : Ambiguous. [Lavini *et al.* 2007]

Figure 2 – Classification of Time Intensity Curves (TIC)

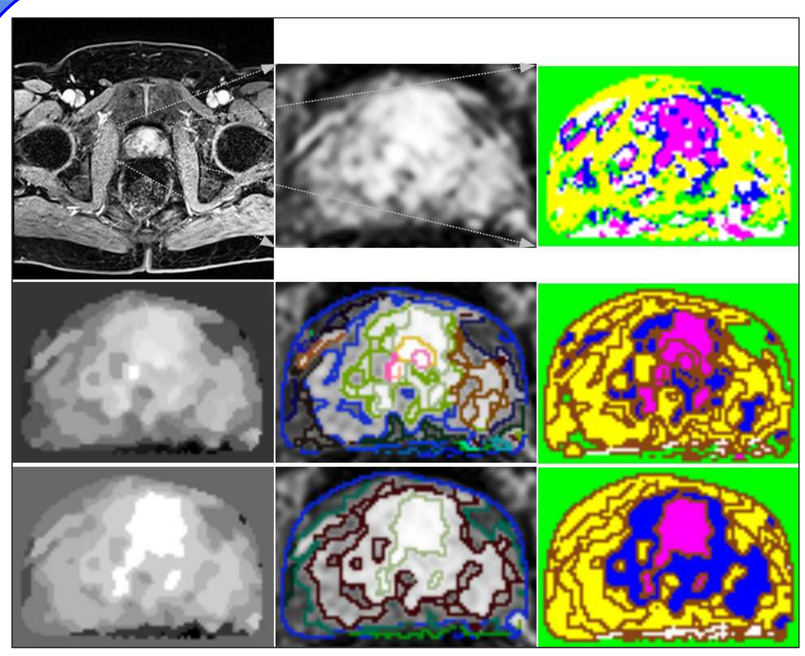


Figure 3-A - HCS process based semi-quantitative analysis
Original image and TIC classification at the start (Row 1)
Heat map, boundaries of HCS regions and HCS regions coloured based on their TIC types (Fig. 2) for 35 HCS regions (Row 2) and 12 HCS regions (Row 3)

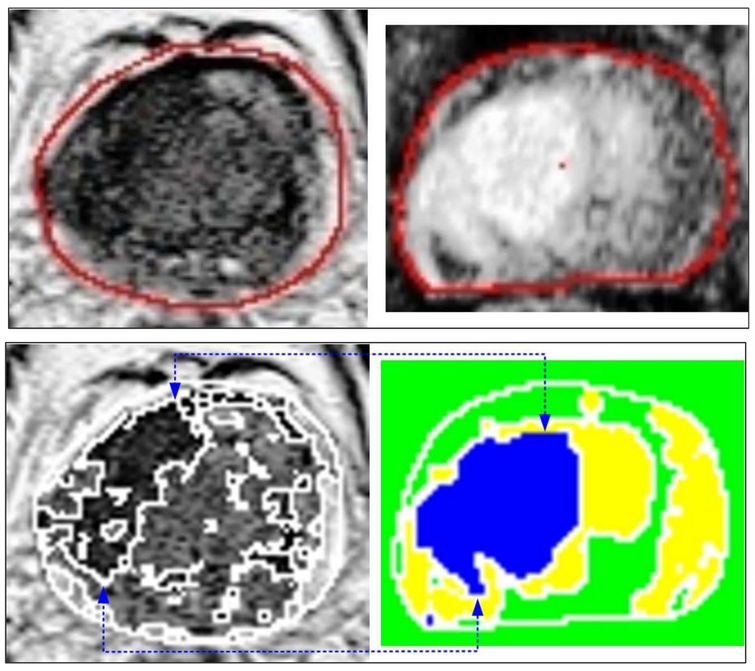


Figure 3-B – T2-weighted (left) and corresponding DCE MR image sections (Row 1) with prostate part outlined
Correlating HCS outlined dark region on T2-weighted with DCE-MRI HCS region classified as carcinoma (Blue region)

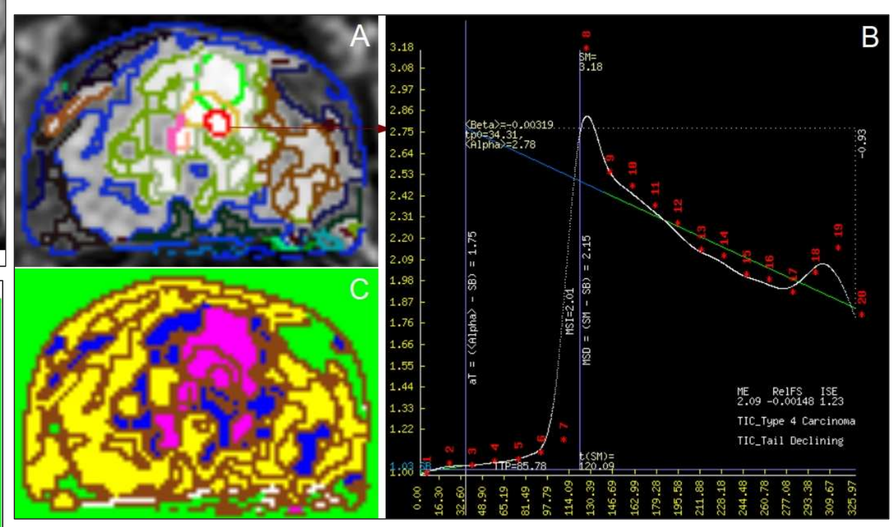


Figure 3-C – (A) HCS aided identified suspicious region (Red).
(B) The suspicious region's Parametric TIC.
(C) Classification of the HCS process' regions based on the 6 types of TIC enhancement patterns (Fig. 2)

Figure 3 – Examples of HCS aided qualitative (3 A, B) and quantitative (3C) analysis of Multi-parametric MR Images of the Prostate

RESULTS

Table below lists the correlation of the radiologist's finding and the HCS process based TIC classification with that of the pathologist's findings.

Except for two false positive classification, for the rest of the cases the HCS based TIC classifier classification corresponds with the pathology finding. Those two false positive cases have been diagnosed correctly as normal by the radiologist.

Radiologist's finding						HCS based TIC classification						Pathology finding
TP	FP	TN	FN	P(TP|A)	P(TN|N)	TP	FP	TN	FN	P(TP|A)	P(TN|N)	Abnormal (A) = 12 Normal (N) = 4
9	1	3	3	75%	75%	12	2	2	0	100%	50%	

Table – Radiologist's interpretation, HCS process based TIC classification and Pathology finding
(TP: True Positive, TN: True Negative, FP: False Positive, FN: False Negative)

DISCUSSION

In discriminating malignant lesions from normal and benign regions, T2-weighted MR images has a diagnostic performance such that it complements the DCE T1-weighted based diagnosis

Tumour in T2-weighted MR image will appear as signal loss (dark). But false positives occur in haemorrhage, calcification, inflammation and fibrosis (post-inflammatory, postoperative, posthormonal (ADT), post-radiation, or following thermal ablation treatment).

So to confirm whether the signal loss in the T2-weighted image is due to tumour, the DCE-MRI TIC based classification is made use of.

In the case shown in Fig. 3B, the corresponding region, where there is signal loss in the T2-weighted image, is classified as Type-3 carcinoma (Blue). Thus HCS aids diagnosis of mpMRI.

IMAGE GUIDED THERAPY

Prostate cancer diagnosis is confirmed using a needle biopsy in the UK. A Trans-rectal Ultrasound (TRUS) biopsy involves taking 10 to 12 cores in a systematic manner. There are number of significant risks and complications arising from TRUS procedure. To minimise such complications HCS process aided targeted biopsy may be taken

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