

Multimodality Texture Analysis Using *FireVoxel*

Background

Quantitative imaging biomarkers based on image texture are used increasingly in radiology. *Texture feature vector*, derived from the signal within the tumor, is often combined with clinical and genetic information to predict patient outcome. Our team is developing texture image analysis software tools within the *FireVoxel* package. This includes DICOM image loading, multi-modality coregistration, 3D lesion segmentation, and computation of texture feature vector for individual cases and as a batch.

FireVoxel algorithm mimics biological patterns of cancer growth by assessing the tumor signal within concentric 3D shells (**Fig. 1**). Biologically meaningful spatial information is obtained by separating the tumor signal into rings within the tumor and the surrounding region. The software combines texture from all available images. This approach enables capturing the spatial variation of texture features that cannot be obtained by conventional methods.

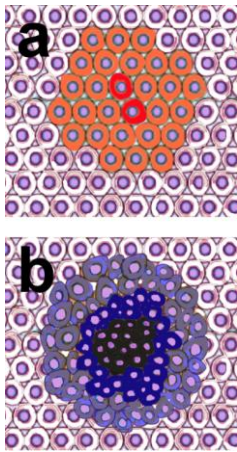


Figure 1. Schematic of cancer growth.

a. The growth of the tumor (orange) within the normal tissue (white/purple) is initiated when one or more mutated cells (red) begin to proliferate abnormally. Further mutations result in increasingly rapid progression of cancer.

b. Late-stage tumor exhibits proliferating cells in the outer layer (gray), a quiescent inner ring (blue) and a necrotic core (black). Necrosis results from a limited supply of oxygen/nutrients and deposition of waste products.

These concentric microstructural patterns is reflected in 3D tomographic images.

To generate texture feature vector, *FireVoxel* executes nested loops:

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L1: for each imaging modality
  L2: for each VOI
    L3: for each spatial scale or "filter size"
      L4: for each concentric inner & outer ring
        compute signal characteristics & append to feature vector
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Notes: Promising modalities include CT, functional MRI, and MRI-derived ADC and K^{trans} maps. L4 may include surrounding rings, inner ring and remaining core (**Fig. 2**). L3 includes the original image and various filtered versions at a given feature size (**Fig. 3**). Signal characteristics include the mean, standard deviation, skewness, kurtosis, and entropy.

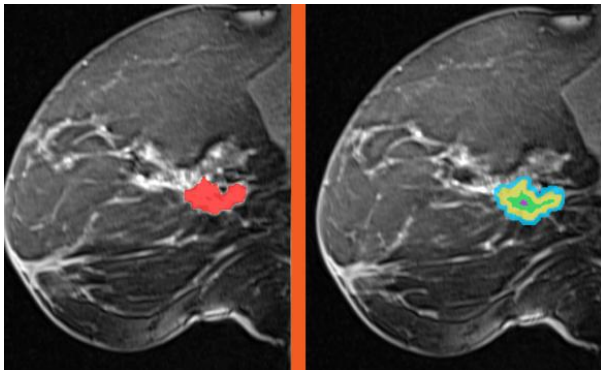


Figure 2. Breast lesion segmentation into concentric rings for texture analysis.

Modality: Fat-suppressed T1-weighted 3D MRI, single sagittal slice shown. The tumor is segmented as follows:

red:	original lesion ROI
blue:	outer ring
yellow:	ring 1
green:	ring 2
brown:	central core

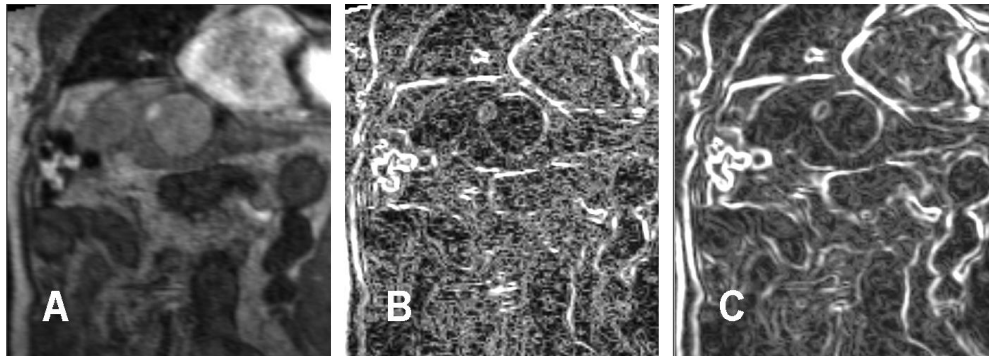


Figure 3. Feature identification on an MRI image by 3D filtering. A: original image; B: the same image filtered by texture gradient sensitized to 1 mm features; C: image filtered and sensitized to 3 mm features.

FireVoxel tool further introduces optional 3D image "filters" that modify the acquired image. The dual goal of filtering is (a) to extract features of given granularity size (see Figure 3); and (b) to suppress image artifacts. Current texture-sensitive filtering is based on the analysis of a spherical vicinity S of each voxel. *FireVoxel* considers all possible splits of S into two distinct hemispheres $\{S+, S-\}$. It identifies one in which $\{S+, S-\}$ have the "most distinct" histograms. Histograms are compared using either simple bin-by-bin difference or using Earth Mover Distance method of Rubner*. This yields at each voxel the texture gradient with magnitude equal to the largest difference between histograms.

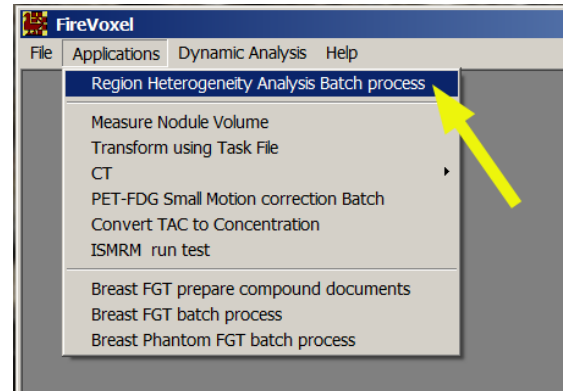
Rubner Y, Tomasi C, Guibas LJ. The earth mover's distance as a metric for image retrieval. *Int J Comput Vis* 40(2): 99-121, 2000.

Batch tool

With no images loaded, select

Applications -> Region Heterogeneity Analysis...

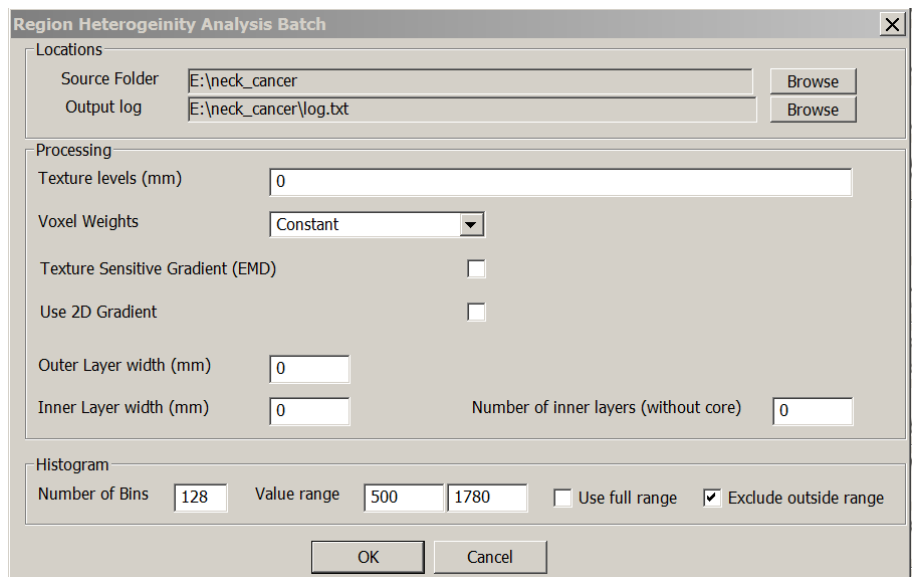
to load the dialog box (next page). All study cases have to be in *.fvx format that allows saving the multiple coregistered images and multiple ROI masks in a single file. It will be important to name image modalities and ROIs consistently across the study



Source folder must contain all *.fvx to be analyzed. folder

Output log is a text file where texture features are saved. The current version computes and saves the mean, st.dev., skewness, kurtosis and entropy.

Texture levels (mm) deals with automatically created texture filters that will be applied to all image layers. If interested in processing the original image and a 3mm filtered image that enhances 3mm size features, enter 0,3 in this box. Filtering can be time consuming, so for the initial testing skip filtering and enter 0.



Voxel Weights, Texture sensitivity, 2D: these are filter parameters. It is best to start with the default settings: Constant, No, No.

Outer layer width (mm): if not zero, the program will automatically make a 3D region of specified thickness. This new ROI is outside the lesion. The histogram features for this new region will be labeled: lesion_or , where lesion is the existing name.

Number of inner layers: if not zero, the program will automatically make inner shells or rings. These concentric rings are all inside the lesion. The histogram features for the first ring will be labeled: lesion_ir1; for the second ring lesion_ir2. The program will also generate the innermost core by subtraction all requested rings from the lesion ROI. The histogram features for the core will be labeled: lesion_co.

Inner layer width (mm): the thickness in mm of each ring. When selecting ring thickness and the number of rings consider what is the smallest lesion size in the study. There is a possibility that some rings will become empty sets.

Histogram: your specification of histogram will have impact on computed entropy. It is best to test this interactively in

Layer Control -> ROI Stats 3D

Histogram features will be refreshed when you click on Update Histogram button.

