SEVENTH FRAMEWORK PROGRAMME OF THE EUROPEAN UNION

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PET-based target volume segmentation

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Partner UKL-Freiburg

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Software for the Use of Multi-Modality images in External Radiotherapy

MARIE CURIE ACTIONS

1. 4D-PET GTV Segmentation Algorithm.

The algorithm is based on a contrast oriented algorithm and adapted to RG-PET/CT images in order to delineate GTV in lung cancer patients.

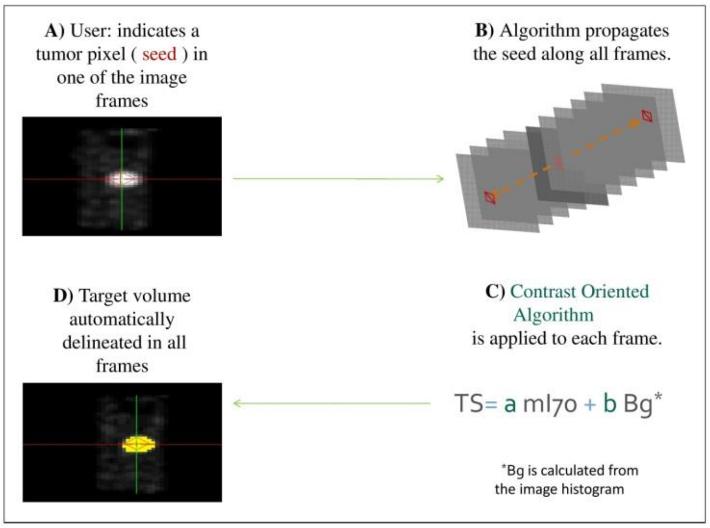


Figure 1

Fig.1 schedules the different steps involved in the semi-automated segmentation algorithm evaluated in this work:

A) The semi-automated character of this algorithm relies on that the user is required to indicate a tumor pixel in one image of the imaging frames.

B) Subsequently, the algorithm propagates the seed along all the frames.

C) In each frame, the contrast oriented algorithm (COA) is applied in order to determine the threshold for volume contouring (TS).

D) All pixels having intensity lower than TS are labeled as non-target whereas those with a higher intensity are considered to belong to the target region.

1.2 Evaluation

The set of images employed for the algorithm evaluation involves 4D PET/CT acquisitions of dynamic experimental phantoms and lung cancer patients.

1.2.1. OPTIMIZATION: Based on Dynamic Phantom Measurements

- The optimization of seeds propagation along the time frames was performed based on 4D phantom measurements with different target movements:
  - sinusoidal regular movement in one and three dimensions with significant respiratory motion contribution
  - irregular patterns that simulate realistic breathing cycles
- Bg determination was optimized based on 4D FDG-PET activity quantification in 10 lung cancer patients. Results from this study showed that the activity distribution within normal structures and the tumor as well as the maximal FDG uptake (site, absolute and relative

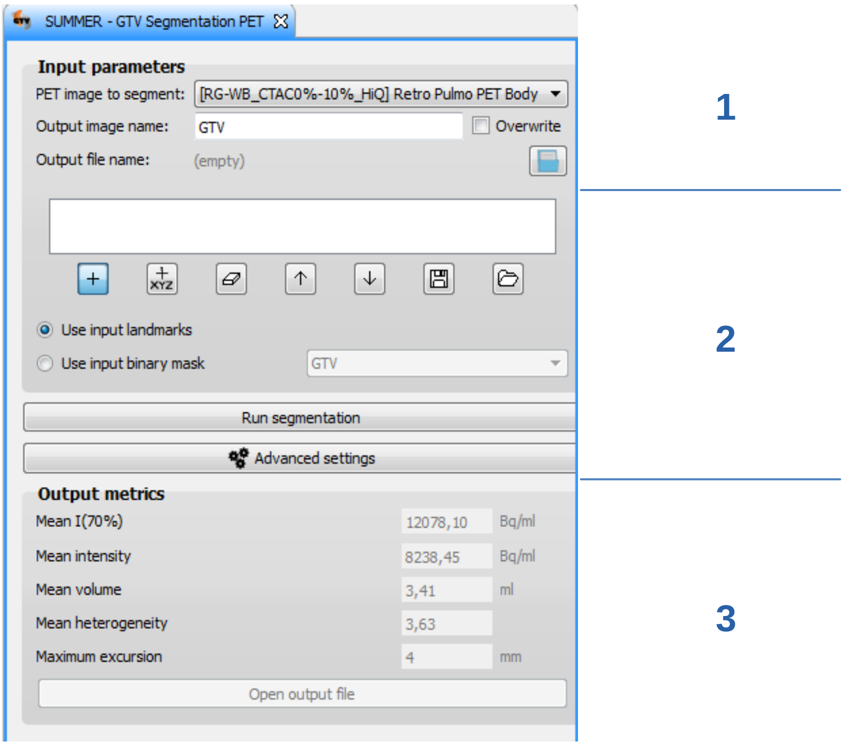
value) is variable from patient to patient. Consequently, the optimal reference value for background computation was determined as the maximum intensity within the tumor.

- Different ways to extend a threshold and region growing based 3D ^{18}FDG-PET segmentation algorithm to delineate NSCLC in 4D PET datasets were analyzed. Based on the above mentioned phantom measurements, one way of contouring a 4D GTV that gives the user the most appropriate results was derived.

1.2.2. VALIDATION: Based on Dynamic Phantom Measurements and Clinical Data.

- In phantom evaluation, true properties of the objects define the gold standard. Algorithm evaluation with experimental phantom measurements results in:
  - no statistically significant diameter differences for different target movements and volumes;
  - repeatability for heterogeneous and irregular targets independently of user initial interaction and
  - accuracy in target tracking position for both experimental phantoms and clinical data.
- In clinical evaluation, the gold standard is the consensus of three manual contours by experts. Lesion position and extension provided by the algorithm is in reasonable agreement with the consensus.

1.3. Plugin



I. Previously to the GTV segmentation.
   - **Use input landmark**: to select the semi-automated segmentation based on initial seed location by the user. Option by default.
   - **Use input binary mark**: to select the semi-automated segmentation based on a lung mask. Option pending of code optimization.

II. Initialization of the segmentation process.

-  : click on it and place the seeds
- **Run segmentation**: click on it in order to obtain the segmented GTV based on the indicated seed position.

⏱ Wait < 1 s.

III. Segmentation Results.

- **Output Metrics.**
  - MeanI(70%), the mean intensity of all pixels within the isocontour defined by 70 % of the maximal tumor voxel intensity (Imax).
  - Mean intensity, the mean intensity of all pixels within the segmented GTV.
  - Mean volume, size in ml of the segmented GTV.
  - Mean heterogeneity, defined as 1/COV. COV (Coefficient of Variance) is the ratio of the Standard Deviation and the Mean of voxel intensities within the segmented GTV.
  - Maximum excursion, maximum displacement of the segmented GTV along the SI (Superior-Inferior) direction.
- **Open output file:** in order to save in a text document the Metrics values for each time frame.

1.4. Derived Applications

A software tool for classifying NSCLC lesions into central or peripheral was developed. It is a highly versatile tool able to fully automated segment trachea, PROXBT, mediastinum, GTV and ITV and which can handle chest CT, full body CT, both with and without contrast agent, FDG-PET and 4D FDG-PET. The segmentations are used to determine the danger zone around the mediastinum, the vertebral body, the PROXBT and the trachea. Then the overlap of the danger zone with the GTV or ITV respectively is calculated. If there is an overlap the tumour was classified as central, otherwise as peripheral. This tool was implemented into the medical imaging toolkit (MITK) framework and gives user feedback via a graphical user interface about the outcome of the calculations. The 4D PET GTV segmentation algorithm is implemented in this tool to accomplish the tumor segmentation on PET.

2. 3D Random Walk algorithm for malignant glioma delineation in amino acid PET-images

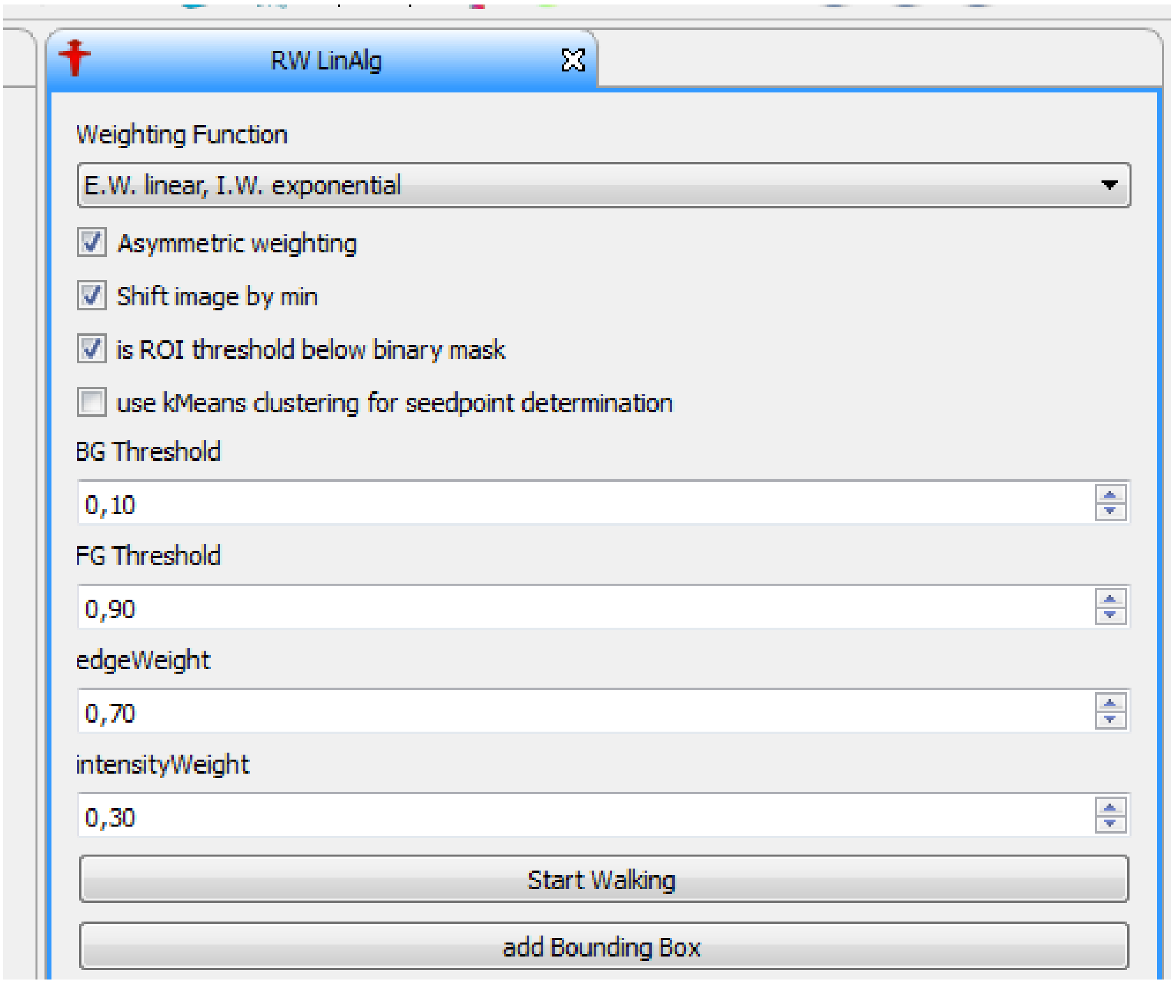
The presented random walk (RW) approach pre-segments a user defined region of interest (ROI) into 3 classes (tumor, background and unlabeled pixels) based on the pixel intensities. Every unlabeled pixel is then assigned to the class which is most likely a random walker would reach first starting from that pixel. The walker is driven by the images gradient field and pixel intensities.

2.1. Evaluation

14 amino acid PET datasets with recurrent high grade glioma were contoured. The RW results were compared to the outcomes of a 40 % threshold, a 1.4 opposite mean (OM) and 1.7 OM threshold method plus the GTV delineated by a clinician.

Results suggest that the RW approach may be a robust method for the segmentation of low contrast PET images. Here, the method outperforms common threshold based segmentation techniques by applicability and robustness against noise.

2.2. Plugin



I. Previously to the GTV segmentation.

- **Weighting Function**: the weighting function can be chosen
- **Asymmetric weighting**, **shift image by min**: influence the weights of the generated graph
- **BG Threshold**: upper threshold for background determination (in percentage of the maximum pixel intensity)
- **FG Threshold**: lower threshold for foreground determination (in percentage of the maximum pixel intensity)
- **Edge Weight, Intensity Weight**: influence the weights of the generated graph
- **Add Bounding Box**: restrict the volume used for calculation with a bounding box

II. Initialization of the segmentation process

- **Start Walking**: start the calculations

🕐 Wait < 1 s.