An Accurate Volume Measurement of Solid Lesions by correcting Partial Volume Effects on CT images

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Abstract— Under digital image processing, medical images have lots of applications like oncological diagnosis of tumors and chemotherapy. Computed Tomography (CT) images are used to capture images of solid lesions like lung or liver. For oncological chemotherapy based therapeutics, estimation of size of tumor is the main task to determine whether the treatment is in right path or not. This means that, after chemotherapy, tumor either grows or shrinks. Due to irregular growth of tumor, diameter of tumor is not a standard parameter to determine the size. Volume is the appropriate method to identify the size. But partial volume artifacts, which arise due to low resolution of imaging device, reduces the accuracy of measurement. Partial volume correction (PVC) which extracts the necessary information from the segmented output resolves this problem. This paper presents a different perspective of accurate volumetric measurement by correcting partial volume effect at the borders of segmentation result.

Keywords - Computed Tomography, Classification, Partial volume effect, Partial volume correction, Boundary map, Distance map

I. INTRODUCTION

In oncology, CT images of solid lesions like lung or liver are used for chemotherapy based therapeutics. For this, volume of tumor on medical images is one of the standard parameters. Measuring the change in tumor size is the best strategy for assessing the cancer. Change in tumor size can be found out by various methods. Diameter measurement is one such method. A diameter is not always an accurate measure to assess the size of a tumor, because most of the tumors grow and shrink irregularly in 3-D description [1]. Volume of the tumor defines the size of the tumor accurately. If the tumors are shrinking and no new tumors arise, then radiologist can identify the therapy is successful. Lung or liver cancer screening is another application that is based on reproducible size measurements of tumor besides chemotherapy assessment with CT which has proven to be the most efficient modality.

According to Frank Heckel, for measuring the size of the tumor, voxel-counting is not a standard approach. This is because of partial volume effect on the borders of segmented output which arises due to limited spatial resolution of CT imaging device [2]. So these artifacts should be under consideration to avoid misclassification of tumors. The partial volume correction is the best remedy for this issue. Segmentation based partial volume correction with spatial sub division is an approach to improve the accuracy and reproducibility of volumetric measurements of tumor. Earlier solution is a segmentation-based partial volume analysis (SPVA) algorithm for lung nodules [3] that is not able to handle appropriately inhomogeneous lesions or lesions surrounded with multiple structures. So Frank Heckel et al. [2] introduced a generic fast algorithm for measuring the volume of solid lesions as well as compact tumors in CT that considers partial volume effects at the border of the segmented output and performs spatial sub division. The spatial sub-division can extract the necessary information for compensating the bad effects of partial volume artifacts.

The spatial sub-division method divides the segmented output into separate spatial sub segments. After that, volume calculation over each sub segments is performed separately. This is time consuming when the size of the tumor or number of sub divided regions becomes larger. To improve the accuracy of volume measurement, the spatial subdivision over the segmented output is modified as each segment covers a homogeneous region inside and outside of the tumor. The accuracy of this system depends on maximum distance d_{max}, a global parameter, for the whole lesion. This parameter can take on different values depending on the size of the lesion. The actual

size of the inner tissue, outer tissue areas, inner partial volume and outer partial volume depends on this global parameter, which in turn decides the accuracy of the calculated tumor volume. This is not applicable for dynamic approaches.

In this paper, a dynamic method based on distance map and boundary map is being incorporated for identifying the basic areas. Considering the fact that partial volume effect occurs at the edges of the segmented tumor, the basic principle behind the proposed system is that the intensity resembles the same value, in the most of the inner part of the lesion. Before volume estimation, determine whether the tumor is benign or malignant. If it is malignant, it requires the further treatment. So volume of tumor estimates after categorized.

The remaining part of the paper is organized as follows. In Section II survey for this work will be described in detail. Section III will be detailed about the proposed method. This paper concludes with a brief summary in section IV.

II. RELATED WORK

In 3-D image segmentation, some voxels will be lost at the border of the segmentation output due to the effect of partial volume artifacts. To overcome this problem, partial volume correction should be performed. There are many methods for segmentation and partial volume correction [4]. Segmentation methods include robust and automated algorithms which is working on CT. Methods for partial volume correction include histogram based analysis combined with Bayesian classifiers [5], methods using reverse and anisotropic diffusion [6], approach for measuring the volume of atherosclerotic plaque in CT based on Markov random fields (MRF) and a modified expectation maximization [7].

To segment lung nodules in three dimensional CT volume dataset in slice–per–slice basis by a robust and automated algorithm is present. Since any completely automated algorithm may fail in a complicated case, it requires user interaction for the correctness of segmentation results [9]. This algorithm can overcome this situation. The automatic segmentation developed for small ellipsoidal lung nodules in a given volume of interest is another method for extraction. This is done by dynamically initializing and adjusting a 3D template and analyzing its cross correlation with the structure of interest [10]. Another three-dimensional method for the segmentation, analysis, and characterization of small pulmonary nodules uses a semi-automatic classification of the target nodule into different nodule models. But formulating mathematical models of each class and developing separate segmentation schemes accordingly made this method a difficult one. A powerful statistical estimation and verification framework for characterizing the ellipsoidal geometrical structure of nodules in the multi-slice X-ray CT images is another approach for segmenting the lesion. But due to irregular nodule growth and the change in shape of lesion is a potential drawback of this ellipsoid approximation approach [11]. Another automated method for 3D image analysis for segmenting lung nodules in HRCT has been proposed. But it is harder to integrate, if there is any dependence on a preprocessing step, as a plug-in to existing workstations or CAD systems [12].

For correcting partial volume artifacts, most of the work focus on techniques like single-photon emission computed tomography (SPECT), MRI as well as PET. An algorithm for identifying the distribution of different material types in volumetric datasets uses a probabilistic Bayesian approach is introduced by D. H Laidlaw [5]. One approach which is based on iterative deconvolution with a 3D maximum likelihood expectation-maximization (MLEM) algorithm for correcting the partial volume artifacts on PET images which arises due to its limited resolution [13]. This method is used for the estimation in unsupervised manner that simultaneously estimates partial volume effects, by means of the locations of tissue boundaries within the image, as well as the different tissue classes [14].

Another method to restore the ideal boundary is by splitting a voxel into sub-voxels and distributing the signal into the sub-voxels is introduced. Each voxel is divided into four or more sub-voxels by nearest neighbor interpolation. The gray level of each sub voxel is treated as materials which is able to move between sub voxels but it is not same as in the case of movement between voxels [15]. There is an anisotropic method to create interpolated 3D images corrected for partial volume without enhancement of noise.

III. VOLUME ESTIMATION BY PARTIAL VOLUME CORRECTION

The method proposed by Frank Heckel et al. [2] is a general form of the SPVA algorithm for lung nodules, which is not able to handle lesions of inhomogeneous nature or lesions with multiple structures around them appropriately. This is because of the partial volume and tissue regions like nodule core and lung parenchyma are estimated once for the whole lesion and a priori knowledge about lesions in CT is also included in the analysis [2]. Besides, the algorithm uses intermediate results from the dedicated nodule segmentation algorithm. So this method is not applicable to results from different segmentation algorithms or after manual corrections to the segmentation result. The spatial subdivision of the segmentation result can overcome these limitations. From this subdivision, extract all information that is necessary for compensating the partial volume artifacts. The accuracy of this system depends on a global parameter, d_{max} for the whole lesion. This parameter can take on different values depending on the size of the lesion. The actual size of the inner tissue area, outer tissue area,

inner partial volume area and outer partial volume area depends on this global parameter, which in turn decides the accuracy of the calculated tumor volume.

In the proposed approach, a dynamic method based on distance map and boundary map is being incorporated for identifying the basic areas. The segmentation of infected area is done by level set based contour segmentation [17]. For this, the foreground and background regions are described in terms of local regions. In-order to optimize these local energies, each point is considered separately and then moved to minimize the energy to be computed on its own region. The local neighborhoods are split into local interior and local exterior regions by evolving the curve to compute local energies. After that, the energy optimization takes place by fitting a model to each local region. The segmentation by Fuzzy C-Means clustering is done for extracting tumor [18]. The neighboring voxels have similar feature values is one of the important characteristics of every image, and the probability that they belong to the same cluster is high. The spatial information is important in clustering of voxels, and this information is utilized in a spatial FCM algorithm. The spatial function is the obtained by the weighted summation of the membership function in the neighborhood of each pixel under consideration.

On the segmented output, calculate the Gray level co-occurrence matrix (GLCM) features for classifying the tumor as benign or malignant. After classification, estimate the volume by finding basic areas based on boundary maps and distance map. Weight of voxels on each region is calculated then clamp the calculated weight to range [0,1] then find the final volume.

The basic principle behind the proposed system is that the intensity of the intermediate output resembles the same value in the most of the inner part of the lesion by considering the fact that partial volume effect occurs at the edges of the segmented tumor. The distance map contains distance of a voxel to the closest boundary. Voxels inside the object have a positive boundary and outside pixels have a negative value. With the help of distance map, basic areas such as inner core, inner tissue region, inner partial volume region, outer partial volume region and out tissue area can be labelled based on their proximity to region boundaries. This is based on inner boundary and outer boundary map. Boundary map is also a matrix which contains 1 for boundary pixels and 0 elsewhere. This can be generated by identifying the edge of the segmentation output. Fig.1 shows the architecture of the proposed method.

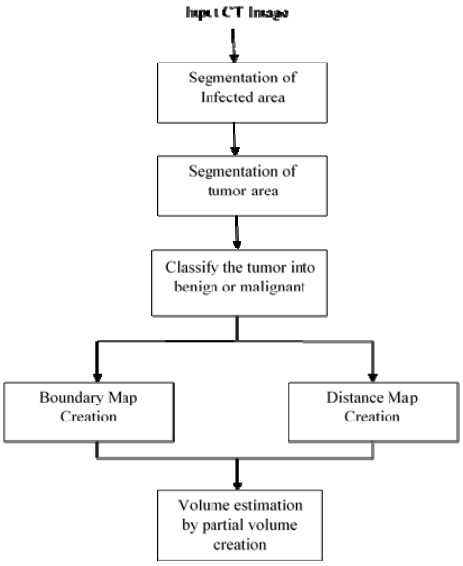

Fig. 3.1 Overall architecture of the system.

The distance map is computed by iteratively applying a morphological erosion operator, starting with an initial binary image. This is the image which has value 1 for each voxel corresponding to the tumor region, and 0 elsewhere. The region shrinks in each iteration while preserving the shape by using an increasing width kernel. The distance map is completed by assigning to each voxel the last iteration number in which the voxel still belonged to the actual (shrunk) region. Clearly, the iteration number determines how far the voxel lies from the nearest region boundary. It is only necessary to iterate until the region is empty. In the distance map, the larger the value for a voxel means that it is farther from the boundary and thus it is less affected by PVE. One simple idea is then, to set every boundary voxel to the innermost average tumor intensity. To exclude extreme values while preserving local features, the mean value of the surrounding innermost or highest labelled voxels is taken. The inner tissue and outer tissue areas are the identified based on the average intensity values.

The proposed system is accurate in terms of volume measurement. There is a great scope for this method in the medical image processing for oncology therapeutics. Volume is a standard parameter for identifying the size of tumor. At every consultation, the volume of the tumor is calculated from CT image of solid lesion. Based on the value of volume the doctor can determine whether the treatment is in right path or not. If the volume is reducing, the dosage of medicine for chemotherapy should be reduced as per the previous prescription.

CONCLUSION

This work has been performed for the 3-D segmentation based partial volume correction which is useful for accurate volumetric measurement of lesions. As tumors grow and shrink irregularly, diameter measurement of tumors and voxel- counting are not accurate parameters for assessing its size. Partial volume artifacts must be taken care of, for the accurate volume measurements. This Paper also suggest another method which is alternative to spatial subdivision for partial volume correction based on boundary map and distance map. By this method, accuracy and reproducibility of volumetric measurement are guaranteed. This method will be efficient and effective in terms of time parameter.

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