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Segmentation of Rectum from CT Images for the Radiation Treatment Planning of Prostate Cancer

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Abstract: **Cancer has been one of the haunted conditions in the society though there have been treatment methods developed to cure. External Beam Radiation Therapy (EBRT) is one such methods of cancer treatment. During the treatment plan phase, the organs at risk in the respective cancer context need to be segmented from acquired medical image. In this work, rectum is segmented from CT images and segmented rectum images are useful in the treatment plan. The work deals with the segmentation of rectum during EBRT plan for treatment of prostate cancer and image processing algorithm developed based on k-means clustering.**

***Index Terms*— External Beam Radiation Therapy (EBRT), Computed Tomography (CT), Prostate cancer, Rectum, K-Means Clustering**

I. INTRODUCTION

Cancer also known as a malignant tumor or malignant neoplasm is a group of diseases involving abnormal growth of the cells with the potential to spread to other parts of the body. Though many diseases may have a worse prognosis than most cases of cancer, cancer is the subject of widespread fear and taboos. Prostate cancer is one which has been commonly seen in men of age 60 and above. Radiation therapy has been the treatment mode opted for treating prostate cancer. When radiation therapy is considered, the delineation of the target organ (cancerous part of the body) and the organs at risk has very high importance. The target organ is manually segmented by the doctor as it demands very high accuracy. Organs at risk are the organs which are at risk of being supplied with dose during the dose delivery to the target organ. Thus, care has to be taken during treatment plan so that the dose to the organ at risk is within the permissible limits and hence the need for the delineation of the organs at risk is very important. Thus, rectum being one such organ at risk in case of prostate cancer needs to be segmented.

The prostate is a walnut-sized gland located between the bladder and the penis. The prostate is just in front of the rectum. The urethra runs through the center of the prostate, from the bladder to the penis, letting urine flow out of the body. The male pelvic anatomy in a human is as shown in the Fig. 1.

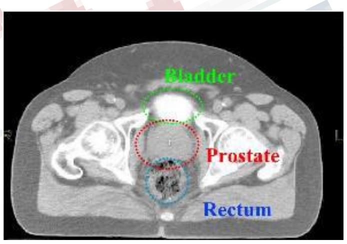
Fig. 1. Male pelvic anatomy in humans

Rectum is the final straight portion of the large intestine in some mammals, and is the gut in others. The human rectum is about 12 cm (4.7 in) long, and begins at the recto-sigmoid junction and terminates at the level of the anorectic ring. In humans, the rectum is followed by the anal canal, before the gastrointestinal tract terminates at the anal verge.

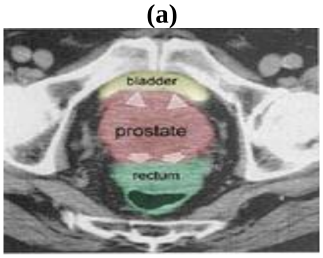
Though cancer can be treated using different methods like surgery, chemotherapy, radiation therapy. The method is selected based on the type of cancer, location and severity. External beam radiation therapy is a method of treating cancer where the cancer cells are exposed to high energy X-Rays which results in their destruction. EBRT planning is a process where given the CT image and prescribed target dose, all the parameters like couch angle, gantry angle, number of beams, and many more are planned accordingly and a dose map is generated. Delineations of regions of interests (ROIs) i.e. tumor (cancerous tissues) and surrounding organs at risk (normal tissues) becomes very important as the normal tissue should not be affected by the treatment plan.

Medical imaging and medical image processing is a domain which is continuously developing and has resulted in the increased knowledge of the normal and diseased anatomy. Thus, efficiency of medical diagnosis and treatment and hence the rate of survival of the patients has increased. Computed tomography is a well-known imaging modality which gives the anatomical information of the site which is imaged. When radiation treatment planning is considered, the tissue density information is of high importance to plan the dose and it can be efficiently obtained using CT modality. CT has a very high repeatability which is another reason for which it is opted for in treatment planning as the radiation treatment is a process carried out in many sittings and the repeatability is much needed in this case. Usually no contrast agents are given to obtain CT in this context as it results in the variation of intensity values and hence the interpreted density values.

Segmentation is the process of extracting the region of interest from an image. Image segmentation in the context of medical applications plays a crucial role as it facilitates the delineation of the anatomical structures and other regions of interest. Segmentation can be manual or automated. Number of people who undergo scan under different imaging modalities is increasing over the years due to various disease conditions and increased population. The computer based image segmentation and processing inevitable. Hence, automated segmentation is applied in many applications of medicine except for those in which manual segmentation is incompetent. Segmentation plays an important role in the applications of medicine which deal with images may it be for diagnosis, treatment or monitoring.



(a)



(b)

Fig. 2. CT images of male pelvic region in humans

Fig. 2 shows the CT images of male pelvic region where, (a) corresponds to normal prostate and (b) corresponds to prostate cancer.

In this work, the objective is to develop an image processing method to segment rectum from the CT images of male pelvic region in the context of radiation treatment plan which is useful for the treatment of prostate cancer.

II. BACKGROUND

The anatomical complexity of organs and due to different disease conditions analysis of medical images is a challenging task for medical doctors. The use of computers for processing and analysis becomes medical images is necessary. The computer algorithms process the images for segmentation of anatomical regions of interest assist and automate specific radiological tasks. The methods of segmentation widely vary depending on the specific application, imaging modality, and other factors [1]. Imaging artifacts affects the performance of segmentation algorithms. Segmentation methods are based on the image modality and tissue of interest. Design of application based method is essential for accurate segmentation and better diagnosis can be achieved. Selection of an appropriate method for segmentation depending upon the modality, the regions to be segmented and the application need anatomical as well as image processing knowledge. Computed tomography is a well-known imaging modality where by capturing multiple x-ray images round the subject, the 3-dimensional information is obtained. It gives the anatomical information of the body part which is imaged [12].

Segmentation methods can be classified in many ways. One such way is to classify them based on thresholding approaches, region growing approaches, classifiers, clustering approaches, Markov random field models, artificial neural networks, deformable models, and atlas guided approaches [1]. Another way of classification is as region-based methods, edge-based methods, specific theory based methods, model-based methods [3]. In region-based methods, the region of interest is segmented out completely using some pre-defined criteria. The segmentation methods which come under region-based segmentation are Thresholding, region based methods (region growing, region split and merge). Classifiers are supervised methods which partition the feature space based on the training data. Clustering methods are unsupervised method where they train themselves using the available data by iterating between the segmentation of the data and the properties of the classes [2]. Clustering methods maximize the intra-class similarity and minimize inter-class similarity [6]. Markov field models method of segmentation goes with the statistical approaches whereas, the artificial neural networks being a very efficient is all about parallel computing [1][2][3]. The large datasets and the increasing complexity makes the use of automated segmentation techniques inevitable and very necessary [7][14]. The atlas based segmentation methods have been proven to be very efficient having the ability to segment complex structures with variable size, shape and properties with the only disadvantage of the need for expert knowledge to build the database. In any medical application where imaging is incorporated, the visualization of the images plays a very important role. Visualization of the volumetric data helps in extracting meaningful information from the data. It helps for diagnosing, treatment planning, treatment monitoring, interactive segmentation and many more applications [8][9][16]. Visualization can be done either using the geometric primitives (surface rendering) or without them (volume rendering) based on the need and the application for which it is done [8][9]. Marching cubes algorithm is one of the surface rendering algorithms. Only surface representations and information can be obtained using the surface rendering methods. The direct volume rendering techniques create a 2D image from a 3D volume. The techniques used may be object order, image order or domain based [9].

Radiation treatment planning for cancer is one such application where image segmentation and visualization play a very important role. In treatment planning for prostate cancer, rectum and bladder are considered are the organs at risk [4]. In [4], these organs are segmented using region growing method. But, this potentially has a disadvantage of human interference to set the seed points. A potential combination of various algorithms is used in [5] to segment male pelvic region i.e., bones, adipose tissue, muscles and prostate thus excluding bladder and rectum. Therefore the segmentation and visualization algorithms in medical applications were studied. The objective was set to segment the bones and rectum of male pelvic CT which finds its application in the radiation treatment planning for prostate cancer. For segmentation of bones, thresholding is used by considering its advantages over other methods [1][2][3][4][10][11][13] in this context and based on the comparative study of various algorithms along decided to use k-means clustering [1][2][3][6], for segmentation of rectum. Morphological operations were used for further processing.

III. METHODOLOGY

A method based on k-means clustering is used for segmentation and visualization of rectum. The image processing steps involved are shown in Fig. 3. The CT image datasets were acquired from two different sources. One was from Orisix PACS and two others from J. S. S. Hospital, Mysuru. Two datasets were corresponding to images taken without any contrast agents administered and one with the contrast agent administered. The obtained images are processed in the sequence shown in Fig. 3 and the output is rectum segmented and visualized image.

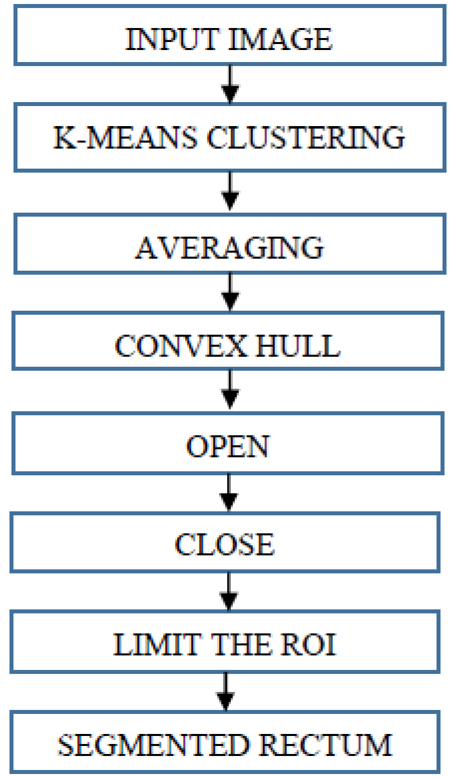


Fig. 3. The image processing steps of segmentation of rectum from male pelvic CT image

K-means clustering being an unsupervised method of segmentation, the input data is classified to the required number of classes. An averaging filter is used to remove additive noise. Opening is morphological erosion followed by dilation. Opening smoothens the contours of an object, breaks narrow isthmuses, and eliminates thin protrusions. Convex hull is used to get the structure given the structural element as per the need. Closing is morphological dilation followed by erosion. Closing smoothens sections of contours, using narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour.

IV. RESULTS AND DISCUSSION

Three datasets were collected, two without contrast and other one with contrast. The algorithm successfully segmented the rectum from the two image data sets where no contrasts were given. The intermediate results of segmentation of rectum are as shown in Fig. 4. In Fig. (a) shows input CT Image, (b) shows result after K-means clustering, (c) shows result after convex hull, (d) shows result after opening operation, (e)shows result of closing operation (f) shows result after applying limits and (f) shows result of 3D visualization of the segmented results for each slice of the dataset (Sagittal view). From the results it can be observed that the developed method is simple and accurate. The developed methods are useful for treatment of prostate cancer.

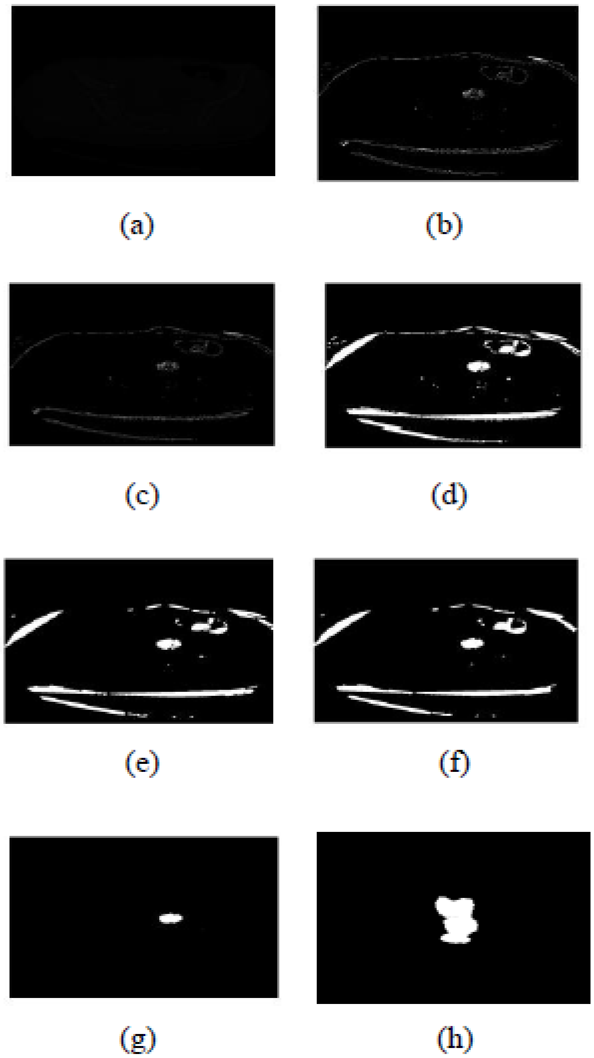


Fig. 4. Stage-wise results of segmentation of rectum in CT image of male pelvic region

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