Fully Automatic Detection Of Liver Lesions In Real Abdominal CT Images

Devendra Joshi
National Institute of Technology, Raipur,
Raipur (C.G.) 492010 India

Dr. Narendra D. Londhe
National Institute of Technology, Raipur,
Raipur (C.G.) 492010 India

Abstract

Computer aided diagnosis and treatment is now in regular practice and it provides the radiologist the early detection of suspicious regions in the various types of medical images. The image segmentation is the most significant and integral part of such diagnosis systems which need to provide the speedy and precise detection of metastases. This manuscript presents the study of liver tumor detection in real abdominal CT images. For this two segmentation methods are evaluated and compared. Firstly, the newly proposed method which includes the segmentation based on adaptive threshold set splitted regions and later merged to form a complete segmented image. Secondly, the well-established watershed algorithm is used whose results are compared with first method. For this study, especial low contrast difference abdominal CT images are used.

Keywords: Segmentation, Region Splitting and Merging, Watershed method, liver tumor.

1. Introduction

Computer aided diagnosis (CAD) [1, 2] is becoming a very important tool in the field of medicine since last two decades. Computer-aided diagnosis is made by a radiologist who uses the information from a computerized analysis of medical images as a 'second opinion' in detecting lesions and in making diagnostic decisions. The final diagnosis is made by the radiologist. These output information include both detection unusual information and diagnostic information on the basis of a comprehensive analysis of existing rules [3]. Currently many present CAD systems targeted at the human organs including breast [4], lung [5], heart [6], brain and uterus etc., and these key algorithms in different CAD system have more similarities and can be reused.

The present computer aided diagnosis algorithm platform (CADAP) [7] uses workflow technology, building component module and framework. The algorithm on the platform needs interface flexibility, information sharing, and safety and efficiency requirements.

Medical Image Segmentation as discussed in above sections, the image segmentation is an important integral part of the CAD systems. The rapid growth in CAD systems has attracted lots of attention to speedy and precise segmentation of medical images. This has motivated the work presented in this report. The automatic segmentation liver metastasis in CT image is the prime concern here. Computer assisted planning of various liver treatments (minimally invasive therapies, oncology liver sectioning, living donor transplantation) is primarily based on computed tomography (CT), which can be an important aid for operability decisions and visualization of individual patient anatomy in 3D [8]. The planning is based on the liver volume, the anatomical liver segments, the vessel structure, and the relation of lesions to these structures. The detection of the boundaries between the segments is then the first step of the preoperative planning [9]. Radiologists currently use CT images with intravenous contrast infusion, in order to detect lesions and vessels in the liver. The key point of the above-mentioned treatments is the liver volume segmentation. However, automatic segmentation methods still have several difficulties [10] which hinder their clinical usage. First, large intensity variance of same target tissue across different patients may happen due to different image acquisition machine, diverse tissue properties across patients and different stages of diseases. Second the large shape variance of the same target tissue across different patients. The shape variance roots from either normal shape variance of different patients or deformed shapes due to diseases and operations. Thirdly, amount of image noise is varied. These difficulties usually cause the automatic segmentation methods not as robust. Mainly, the liver is approximated to muscle and gastrointestinal tract. Since adjacent organs have similar intensity with the liver, a direct liver-extraction or tumor approach without pre-processing may also extract undesirable boundaries resulting from its adjacent organs as fault positive/negative errors. Healthy cells reproduce and die in a stable and orderly manner, under some cases however, a group of cells start to grow uncontrollably and produce a tumor. Tumors can be benign, lacking the capacity to spread to other organs, or malignant. The malignant tumor display uncontrollable growth and may invade and destroy healthy surrounding tissue or even spread to other organs and continue the destruction there. Spread tumors are called metastases. Tumors in the liver may belong to the same categories [12]. The most common primary hepatic tumor is Hepatocellular carcinoma or HCC which accounts for 80-90% of the cases.

2. Method

The segmentation procedure of liver tumor is proposed by using abdominal CT images. DICOM CT liver images have taken for analysis purpose. Tumor segmentation in CT liver images is a challenging task. The segmentation of liver tumors is challenging due to the small observable changes between healthy tissues and tumors. A normal liver with no tumor, such as liver cancer or liver cirrhosis, shows regular gray values in an abdominal CT image. The gray value of a normal liver ranges between 90 and 92 out of gray values from 0 to 255. However, the tumors of the abnormal liver do not have regular gray values between 90 and 92. CT is the most commonly used imaging technique for the inspection of liver tumor. It helps doctors to acquire the information and provide opinions for liver tumor. Many research groups have developed different approaches for liver and tumor segmentation. They all give different types of approaches and algorithms for automatic liver tumor segmentation.

This section describes the proposed segmentation method and watershed method for tumor detection in CT images of liver. For the analysis purpose CT images is collected from scan centre with details information about liver tumor in CT images. Proposed method uses Region of Interest (ROI) techniques along with adaptive thresholding for the detection of tumor in the CT images of liver. Next the performance evaluation is done using the proposed method and the watershed method of tumor detection in CT images of liver.

2.1 Proposed Segmentation Method

Proposed segmentation method uses Region of Interest (ROI) method along with adaptive thresholding for detection of tumor in CT images of liver. The ROI method uses region splitting and merging algorithm. First, the method subdivides the entire image into smaller regions following a dissimilarity criterion which is called region splitting. To divide the image, different strategies can be adopted such as a quad tree partition (where each region is subdivided into four equal regions) and a binary space partition (BSP) (where an optimal partition is selected to divide the region). Second, the neighbour regions obtained from the splitting step are merged if they verify a similarity criterion. These similarity and dissimilarity criteria can be based on an intensity range, gradient, contrast, region statistics, or texture. The combination of splitting and merging steps allows for the segmentation of arbitrary shapes, which are not constrained to vertical or horizontal lines, as occurs if only the splitting step is considered.

2.2 Region Splitting and merging

Region splitting and merging subdivide an image initially into a set of arbitrary, disjoint regions and then merge and/or split the regions in an attempt to satisfy the necessary conditions.
Let R represent entire image region and select a predicate P:-

Split into four disjoint quadrants any region R_i for which $P(R_i)$ = FALSE.

Merge any adjacent regions R_j and R_k for which $P(R_j \cup R_k)$ = TRUE.

Stop when no further merging or splitting is possible. Several variations of this theme are possible ex:-

Define P (R_i) = TRUE if at least 80% of the pixels in R_i have the property [Z_i - M_i] < = 2ϱ.

IF P (R_i) = TRUE the value of all the pixels in R_i are set equal to M_i.

Splitting and merging are done using the algorithm on the previous transparency Properties based on mean and standard deviation attempt to quantify the texture of a region. Texture Segmentation is based on using measures of texture for the predicates P (R_i).

The process of region splitting and merging is proposed or designed. According to the following criteria:-

1 The method should be robust against partially weak edges and noisy homogenous region in object.

2 The method should be robust against different object border orientation and position.

3 The method should be robust in small geometrical translations of the images at instance of registration error.

4 The method should be computationally efficient in the number of split and merge operations.

2.3 Adaptive thresholding

Thresholding is called adaptive thresholding when a different threshold is used for different regions in the image. This may also be known as local or dynamic thresholding. Adaptive Thresholding subdivide original image into small areas and utilize a different threshold to segment each sub images. Since the threshold used for each pixel depends on the location of the pixel in terms of the sub images, this type of thresholding is adaptive. An approach to handling situations in which single value thresholding will not work is to divide an image into sub images and threshold these individually Since the threshold for each pixel depends on its location within an image this technique is said to adaptive. We use the adaptive thresholding for segmentation of liver tumor in CT images. Threshold process convert CT image in to binary image. Image Segmentation for subimages without boundaries, variance < 75, so when variance < 100, subimages treated as a single composite image or subimages with boundaries, variance > 100, so when variance > 100, subimages treated separately. In both these cases T is obtained automatically with T0 midway between the minimum and maximum gray level. This process will automatically generate segmented region using gray level.

Table 1: Abdominal CT data set detail

Patient No.	CT SCAN	Diagnosis
1	CT scan whole abdomen(plain & contrast study)	Medial limb of right adrenal gland appears thickened.
2	CT scan upper abdomen(plain & contrast study)	Mild hepatomegaly with two large hypodense peripherally enhancing SOL in liver.
3	CT scan whole abdomen(plain & contrast study)	Evidence of III defined mass with irregular margins showing non-enhancing necrotic in left lobe of liver.
4	CT scan whole abdomen(plain & contrast study)	Hypodense soft tissue mass showing irregular enhancing margins is noted in right lobe of liver.

3. Watershed Method

Here Marker-Controlled Watershed Segmentation method for separating the objects in image is one of the more difficult image processing operations. The watershed transform is often applied to abdominal CT images. It finds "catchment basins" and "watershed ridge lines" in an image by treating it as a surface where light pixels are high and dark pixels are low. The process of segmentation using the watershed transforms

works well if you can identify, or "mark," foreground objects and background locations.
Marker-controlled watershed segmentation follows this basic procedure:

1) First compute a segmentation function. Abdominal CT images whose dark regions are the objects we are trying to segment.

2) Second step compute foreground markers. Dark regions are connected with blobs of pixels within each of the objects.

3) Third step compute background markers. Pixels they are not part of any object.

4) Fourth step modify the segmentation function so that it only has minima at the foreground and background marker locations.

5) Fifth step Compute the watershed transform of the modified segmentation function.

6) Process ends the result visible.

4. RESULTS

In this work, the CT images showing liver metastases are used for evaluating the algorithm. The images are acquired by the trained radiologist and the abnormalities rare confirmed by the expert physicians at (Bhilai) local Scan and Research Ltd., Bhilai, India. The CT images are acquired by Philips CT Scanner. The number of images generally acquired for a single patient is around 100 and it depends on the healthy or unhealthy patients. The DICOM images produced by CT scanner are of size 550 KB each which is very huge to transmit for teleconsultation and to store as well. The most suitable images for the defined problem in this are selected form the set of images for each patient with proper consult of radiologist and physician. The DICOM images are firstly converted into JPEG format using the Sante DICOM Viewer tool. The relevant sample images of patients which are showing the liver lesions significantly are used in this study.

4.1 EXPERIMENTAL RESULTS

As discussed above, the proposed methodology is applied to the above real CT image dataset. The dataset includes specifically the liver CT images which show the lesions of diagnostical importance which are difficult to segment using the existing approaches. The lesions in the CT images have very low contrast difference and diffusing boundaries with the background which makes them visually and computationally difficult to separate. The performance of proposed method is evaluated and compared with the state of art watershed segmentation algorithm from the literature.

Proposed Method- As per proposed methodology, the test image is divided and subdivided in regions of our interest. And the adaptive thresholding is adapted in each region. The general adaptive threshold value is found for the first region and then same threshold is unsupervisely learning from region to region. The segmented regions are later merged to form complete segmented image as shown in Figure 1 (a)-(d).
The red and green marked regions in Figure 1 (a)-(d) show the resultant segmented liver lesions. The performance of the proposed method is found best in Figure 1 (b) and worst in Figure 1 (a). In Figure 1 (a), the segmented region is not fully occupying the suspicious region suggested by the radiologist. In Figure 1 (a), the lesion is surrounded by regions of various other distinct grey levels and shows boundary overlapping which may not be able to get separated perfectly in the subdivided regions. In Figure 1 (b), both the suspicious lesions are detected precisely and some unwanted dots are also created which must be happening the repeated threshold values in subdivided regions. This can be corrected using the restriction not to repeat the threshold values during segmentation of all regions. Similarly, in the Figure 1 (d), as the suspected region is of very small size, the overlapping is occurring with the surrounding regions. The detection in Figure 1 (c) shows promising results. The boundaries are fine and the complete region is detected without any unwanted detection in rest of the image.

Watershed method- The watershed method considered as a difficult segmentation operation comparing with other image segmentation techniques. This method is useful in medical field because it is solve the overlapping between the closest grey levels in medical images. In this section we will explain the obtained results. Firstly the gradient magnitude was obtained and the edges of the input images were determined. We compared the application of watershed method with and without marking the region of interest (ROI) and background. The watershed method is useful only when making markers for background and ROI. The over segmented image which represent the application of watershed method without marking and this result considered as useless result in medical imaging. From the above method the markers is necessary for each ROI and background to be useful special in medical field. The markers computation was done by using the morphology operation technique called opening by reconstruction and closing by reconstruction to clean up the image from stem and dark spats and removing the small blemishes without affecting the overall shape of the segmented objects. The marking step required to calculate the regional maxima and minima to get good markers for ROI as well as background. Here, making markers is avoided in this work of CT image segmentation using watershed algorithm to make comparison fairer.

The complete test CT images composed of detected regions shown with various colors as the outcome of segmentation using watershed algorithm is presented in the Figure 2 (a)-(d). In watershed method, the all closed boundaries are presented with the various colors. From Figure 2, it is easily observed that the highly contrast regions are detected precisely. The low contrast regions are overlapping with each other. The liver in Figure 2 (a) is presented with purple color with lesion in the same presented with dark purple which little less distinguishable. Similarly, the suspicious regions in Figure 2 (b) are recognised as two separate regions but the detection is quite extended to the surrounding region. This confirms the boundaries of the lesions are of very low contrast. On contrary, the suspicious regions in Figure 2(c) are detected with same color and appear as a merged region. While in Figure 2(d), as the lesion is of very small size, the detection is very poor. In both the methods, the adaptive thresholding is adapted.

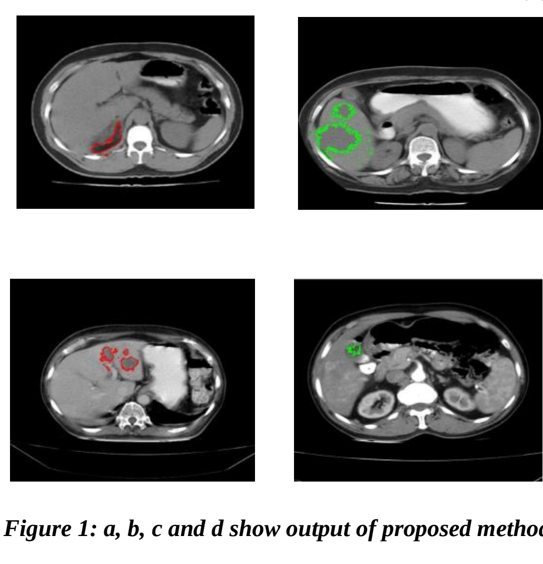

Figure 1: a, b, c and d show output of proposed method.

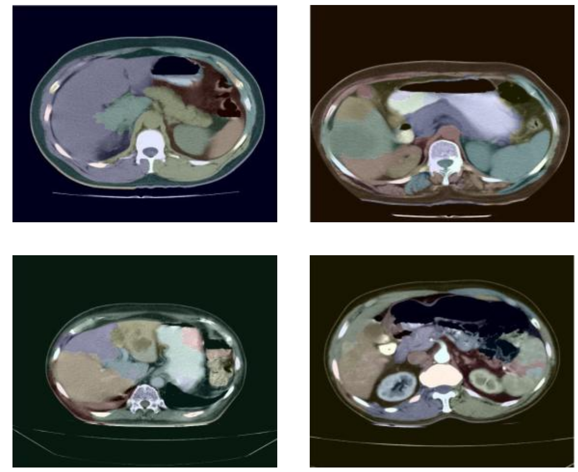

Figure 2: a, b, c and d show output of watershed method.

5. Conclusion

Medical image segmentation definitely has a large potential in the medical domain. Region splitting and merging, Watershed Segmentation method can be used on a large variety of images and in a wide area of applications. This article shows a segmentation algorithm for abdominal liver CT images. Further obtained segments can be used for content based medical image retrieval as a diagnostic aid. We have applied segmentation tools on selected and difficult abdominal CT images of liver which are obtained from scan centre, dataset that offers the opportunity to perform the proposed research. Because of weak boundaries region between normal tissues and tumors, it is difficult to visually inspect and diagnose the liver lesions. The malignant lesion of very small size may get neglected so automatic detection is the only possible solution to fight the life taking disease like liver cancer. The first conclusion that can be made is that the watershed method, using only the image based data term, is too weak to segment liver tumors with varying intensity level and weak borders. While the proposed technique has improved recognition, less ambiguity and it is easy to use. Region splitting and merging process can be used to segment all types of liver tumor but watershed algorithm can be explained by the size of the tumor and its inhomogeneous region. This can be seen always in the case of carcinoma tumors (CHC, CCC,...) etc. The second thing to be observed is that the execution time required in proposed technique is very large as compare to watershed method. The computational burden is very large as it involves the division, subdivision and much more region splitting required as per the type of image.

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The individual thresholding of each region and later merging all the segmented regions makes it expensive in computational time and efforts.

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Biographies

Devendra Joshi was born in Bhilai in India, on April 19, 1986. He graduated from Govt. Engg. College, Raipur,Chhattisgarh in 2009 and student of M.Tech Computer Technology at National Institute of Technology Raipur, India. His areas of interest are image processing, medical image processing.

Dr. Narendra D Londhe is graduated from SSGMCE Shegaon in 2000. He completed his M.Tech and PhD from IIT Roorkee in the years 2004 and 2011 respectively. He is presently working as Assistant professor at National Institute of technology Raipur.
His areas of interest are medical signal and image processing, medical ultrasound and biometrics.