Cyst Segmentation Using Filtering Technique in Computed Tomography Abdominal Kidney Images

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Abstract
Renal cysts, which are very common in human kidneys, can cause hypertension, kidney failure and dysfunction of the kidneys. In this study, kidney cyst segmentation was performed using filtering techniques. Otsu threshholding, Gaussian, Unsharp, Bilateral, Total Variation, Median and Basin Algorithm were used. CT abdominal images were used and images were taken from the GE Brand BrightSpeed device.
Keywords: Segmentation, Otsu Tresholding, Watershed Tresholding

Introduction

Texture is important in machine vision processes such as surface inspection, image classification, and shape detection. The texture is characterized by the distribution of gray levels in a region over the area. Resolution in the image determines the perceived scaling in the tissue. There are three elements in texture analysis. Tissue classification, tissue segmentation and separation of region from tissue.

Texture segmentation is concerned with automatically identifying lines between textural areas in an image. Knowledge-based and border-based applications were used to segment images with textures. Tissue segmentation is an active area of research and there are many methods designed for specific applications.

Medical imaging evaluations based on computer algorithms gain importance due to their accuracy and applicability to various aspects and different dimensions. During the review of the image, the problematic part can be removed and evaluated using appropriate methods to evaluate grayscale and RGB images.

The segmentation method used in the examination of medical images is used to separate the infected area from the image during the examination and healing process. Segmentation combinations are used to evaluate a disease classification. Due to their accuracy the features extracted from the segmented image, it is used to develop and implement machine learning systems based on the diseased region. In addition, the segmented region information can be used in machine learning to further improve detection accuracy [1,2,3].

Separation of relevant areas from images is a process that supports the examination of damaged areas in images with diagnostic accuracy. Various segmentation applications can be found to do this process.

When the studies in the literature are examined, filtering methods have an important place in image processing, especially in medical imaging.

Liver segmentation was performed on computed tomography images taken from the abdominal region [4].

MR brain tissue was segmented using the median filter and fuzzy c mean [5]

Segmentation algorithms were used by using knee images on the Mr device [6]

CT abdomen images were used in this study. After image enhancement studies were carried out and clarity was achieved in the images, reference values were changed and areas of interest were obtained. After removing noise from the image with sharpness value, the threshold value was found. Tissues were segmented in the abdomen image using basin segmentation. In the segmentation of the cyst in the kidneys, the kidneys were determined by using the threshold values and the cyst was segmented as a result of the morphological process. Segmentation was carried out by installing openCV, scikit-image, skimage, math, numpy libraries in the Python environment.

Material and Method

1. Database Used

The dataset used to segment kidney cysts is taken from the GE Brand Brightspeed device. Obtained from Istanbul IYITEM Imaging Center. In the data set with 1018 kidney images, 708 of them have kidney cysts. An example image of the data set is shown in Figure 1.

Fig 1. Contrast-enhanced CT Image

2. Image Enhancement

Sharpness studies were performed on the whole image at different wavelengths.

2.1 Otsu-Tresholding

The Otsu method starts with the estimation of the final solution points. It searches iteratively, maximizing the weighted variance between the background and foreground classes to search for the optimal threshold point [7]. Probability theory measures the weights of classes. It is believed that the variance between classes (separability) is maximized by minimizing the within-class variance (similarity). If the desired maximum variance between classes is achieved, the threshold is chosen as the optimal histogram data threshold. However, noise always occurs in practical applications and affects the accuracy of this method [8]. The single size of the histogram is insufficient to overcome this problem. For this reason, the two-dimensional (2D) Ostu method is used [9]. The 2D histogram presents the original image pixel distribution on one side and the average neighborhood image on the other. Therefore, the resulting threshold is the amount of vectors, which improves segmentation results. However, the computational cost increases. The diagonal areas of the 2D histogram represent the background and foreground. Most of the time is spent on calculating the areas of triangles. The 2D histogram refers to in three integral images (i.e., pixel count integral image, original image density integral image, and average intensity integral image). Instead of using the vector value, i.e. two values, in all calculations, the three integral display values are directly swapped to calculate only the average value [8].

2.2. Gaussian Filter and Unsharp Filter

The Gaussian filter depends on the standard deviation they (distribution) of the image and assumes that the mean is zero (a non-zero mean can also be defined). Gaussian filters are not about edges. Define the value of a particular statistical parameter and are used for basic image blurring. It is usually run by defining a kernel. If a 3×3 kernel is defined, this kernel is applied to every pixel in the image and the result is averaged.

The degree of smoothing of a Gaussian filter is graded in sigma. A larger sigma means greater smoothing. Too much smoothing creates blur in the image.

The unsharp filter is applied to highlight the edges of the image. The three parameters of the filter are the radius parameter, which determines how much of the neighboring pixels on the edges will be affected, the percentage parameter, which determines how much of the edges are dark or light, and the threshold parameter, which defines how far apart the closest tonal values should be before the filter applies something.

2.3 Bilateral Filter and Total Variation Filter

To soften an image and keep the edges intact, a two-sided filter is used. The pixel value is replaced by the neighbor average. This is a nonlinear smoothing approach that takes the weighted average of neighboring pixels. Neighbors are defined as two pixel values that are close and similar to each other. The Bilateral Filter has four parameters to find the image to be smoothed, the diameter of the pixel area i.e. the area to search for descriptive neighbors, the sigma value for Coloring (to find similar pixels), and the sigma value needed to find the pixels that are closer to the gaps.

Total Variation (TV) noise removal filtering is introduced by Rudin, Osher and Fatemi [10]. Its basic idea consists in minimizing the overall variation of the image while maintaining similarity to the original image [11].

The use of TV filtering in CT medical imaging provides sharper images with lower contrast than those obtained with the bilateral filter. Since contrast loss corresponds to the preservation of image discontinuities, it does not include better image quality as an overall effect. TV noise reduction in CT images does not appear to represent an improvement in the images obtained in terms of similarity to the reference image when compared with the bilateral filter, indicating that there is no significant difference between the two methods.

2.4 Median Filter

The median filter is a nonlinear digital filtering technique. Median filtering is widely used in digital image processing because under certain conditions it preserves the edges of images while removing noise, and its output value is a nonlinear filter that is the middle element of a sequenced array of pixel values from the filter window. The median filter filters each pixel in the image in turn and its immediate neighbors are used to decide whether it represents its surroundings [12]. The median filter replaces the pixel value with the median of these values. That is, the values from the surrounding neighborhood are first sorted in numerical order and then the value of the pixel in question is replaced with the middle (median) pixel value. The viewport is called the window. The window has various shapes centered on the target pixel. The median value of the pixels is the value of one of the neighboring pixels in the window. Therefore, the median filter is very unlikely to generate unrealistic new pixel values. Therefore, the median filtering technique is very good at preserving sharp edges [13]. When the skimage and cv2 algorithms are applied to the original image in the Python environment, it has been determined that the skimage algorithm reduces the noise.

2.5 Threshold Value

Thresholding is used to segment objects from the background [14,15]. Whenever possible, it is useful to calibrate detected feature values (eg gray level) so that a given amplitude range represents a unique object characteristic. For example, there are several useful adaptive thresholding schemes based on examination of local neighborhood histograms or other measures. Unfortunately, these approaches can generate a significant amount of noise and in this application such noise will be a major problem due to the small target sizes. The thresholding scheme used for this application to minimize the problem is based on the overall mean and variance of the portion of the image being processed.

3. Segmentation

Image segmentation is the grouping of pixels into multiple segments or clusters of pixels, similar to criteria such as texture, density, or color, to find elements and boundaries within an image [16]. There are many algorithms for medical image segmentation, such as graph cutting, level set, edge detection and clustering. Medical image segmentation aims to divide images into homogeneous segments that concern other pixel neighbors. The results of image segmentation are processed by separating a series of segments, regions or contours of the image. Pixels in an area have many similar or calculated properties, such as contrast, texture, color, and grayscale [17].

Image segmentation is the division into several discrete areas, specifically images with the same characteristics such as color, texture, and density. Image segmentation is used in many applications such as cellular network architecture, color texturing based on an image segmentation workspace, cellular network and medical image segmentation. Medical image shredding aims to identify tissues such as cysts, brain tumors and breast cancer from images with interesting abnormalities [18].

In medical imaging, applied segmentation is normally used to extract the area to be examined from the clinical-level test image for evaluation and treatment planning. The combination of multi-level thresholding and segmentation is used by researchers to examine a class of diseases using images.

3.1 Watershed Algorithm

Assuming that the images are regions dependent on homogeneous intensity levels, it should be possible to extract these regions using some neighborhood features other than spectral features, as in histogram-based segmentation techniques. High grayscale variation between two neighboring pixels may indicate that these two pixels belong to different objects. It combines the morphological approach to image segmentation, region amplification and edge detection techniques. It groups the image pixels around the regional minimums of the image, and the boundaries of adjacent groupings are positioned precisely along the peak lines of the softened image. This is achieved through a transformation called the watershed transformation [19].

Basin computation is a related technique to thresholding as it works on a grayscale image. This technique divides the image into several basins, which are areas of an image where rain will flow into the same lake. To calculate such regions is to fill the image in all local minima and label the places where different evolving components meet. The whole algorithm is implemented using pixel priority order and width priority search [20].

Because images rarely have dark areas separated into lighter regions, watershed segmentation is often applied to a flattened variant of the softened image, making it usable with color images. Alternatively, the maximum directed energy [21] in a steerable filter can be used as the basis for the directed watershed transformation developed by Arbelaez, Maire, Fowlkes et al [22]. Such techniques find smooth regions separated by visible boundaries. Since such boundaries are what active contours usually follow, active contour algorithms [23,24] often precompute such segmentation using the watershed technique.

However, watershed segmentation associates a unique region with each local minimum, which can lead to over-segmentation. Therefore, watershed segmentation is often used as part of an interactive system where the user marks the core locations corresponding to the centers of different desired components [25].

The output of the basin study can be seen in Figure.2.

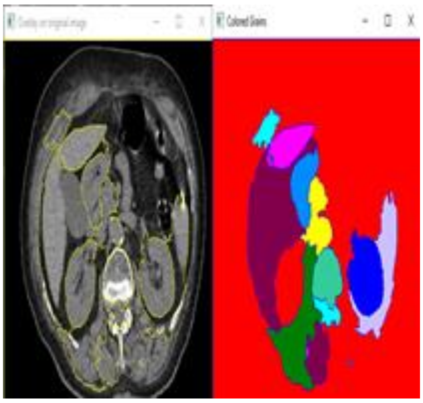

Fig.2 Watershed Study

4 Discussion

On the other hand, in Figure.3, the image of the kidney with cyst taken between 135 and 150, which is determined as the reference area, is seen. This value between 135 and 150 is seen as the best value that can be considered in the study.

Fig.3 Image of Kidney with Cyst taken between Reference 135-150

According to the basin and threshold value algorithms used in the Python environment, the pixel values of the images obtained from the sample study are as follows.

$$\begin{bmatrix} 163 & 163 & 163 \\ 173 & 173 & 173 \\ 179 & 179 & 179 \end{bmatrix}$$

...

$$\begin{bmatrix} 154 & 154 & 154 \\ 193 & 193 & 193 \\ 164 & 164 & 164 \end{bmatrix}$$

$$\begin{bmatrix} 164 & 164 & 164 \\ 181 & 181 & 181 \\ 185 & 185 & 185 \end{bmatrix}$$

...

$$\begin{bmatrix} 149 & 149 & 149 \\ 176 & 176 & 176 \\ 144 & 144 & 144 \end{bmatrix}$$

$$\begin{bmatrix} 161 & 161 & 161 \\ 181 & 181 & 181 \\ 164 & 164 & 164 \end{bmatrix}$$

...

$$\begin{bmatrix} 151 & 151 & 151 \\ 137 & 137 & 137 \\ 129 & 129 & 129 \end{bmatrix}$$

...

$$\begin{bmatrix} 201 & 201 & 201 \\ 250 & 250 & 250 \\ 250 & 250 & 250 \end{bmatrix}$$

...

$$\begin{bmatrix} 180 & 180 & 180 \\ 165 & 165 & 165 \\ 255 & 255 & 255 \end{bmatrix}$$

$$\begin{bmatrix} 171 & 171 & 171 \\ 206 & 206 & 206 \\ 255 & 255 & 255 \end{bmatrix}$$

...

$$\begin{bmatrix} 202 & 202 & 202 \\ 179 & 179 & 179 \\ 249 & 249 & 249 \end{bmatrix}$$

$$\begin{bmatrix} 110 & 110 & 110 \\ 114 & 114 & 114 \\ 139 & 139 & 139 \end{bmatrix}$$

...

$$\begin{bmatrix} 216 & 216 & 216 \\ 214 & 214 & 214 \\ 250 & 250 & 250 \end{bmatrix}$$

Considering the pixel values, the cyst in the kidney was successfully segmented. In Figure 4, the cyst is circled in red.

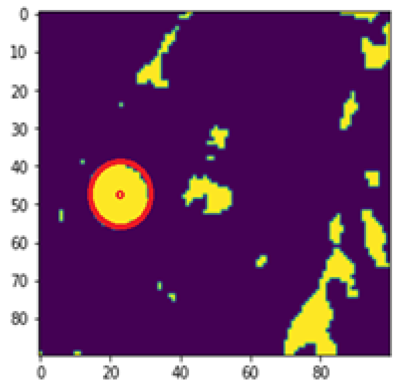

Fig.4 Image of Segmented Cyst Marked in Red

5 Conclusion

Image processing in medical imaging has had a major impact on diagnosis and treatment. The most important part of image processing is image segmentation. Today, imaging in medicine has become very important in medical diagnosis and treatment. In medical imaging, which plays an important role in medical practice, doctors have become even more eager to explore internal anatomy [26]. Many applications based on cross-sectional imaging are being developed, such as Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) or other tomographic modalities (SPECT, PET and PET/MR) [27,28].

Medical image processing has a huge impact on medical applications; For example, the surgical use of image segmentation and image recording in surgical procedures has become widespread.

Image segmentation is the most important part of medical image processing. Image segmentation is the extraction of the region of interest in an automated or semi-automatic process. Many image segmentation algorithms are used to segment tissues and body organs in medical applications. Tumor detection and segmentation, brain development study, functional mapping, automatic classification of blood cells, mass detection in mammography, heart segmentation and cardiac images etc. are some of the areas where segmentation is used [29,30,31,32]

In medical studies, segmentation is used to separate different tissues from each other by extracting and classifying features. The purpose of segmentation is to classify image pixels into anatomical regions by removing bones, muscles and vessels. For example, dividing the image into different region colors, such as white and different gray spectra, can be useful in identifying cerebrospinal fluid, white matter, and gray matter in brain images [33]. This procedure may also be useful in deconstructing breast tumors in medical imaging [34].

The importance of medical imaging is increasing day by day. Thanks to the developing imaging techniques, the accuracy of the diagnosis makes it possible to perform the intervention, which is important for both the patient and the doctor, as soon as possible.

With the medical segmentation, it is easier to find the cyst or tumor in deep learning applications. Today, the advancement of computer hardware makes deep learning a part of medical imaging. Artifact images can be eliminated by performing image restoration using deep learning algorithms in GE Brand 3T MR devices. No segmentation analysis of kidney cysts was found in the literature review. Segmentation of kidney tumors by deep learning was performed [35].

However in this study, kidney cysts were segmented using filtering techniques without using deep learning method. With the filtering method, the hardware required in deep learning algorithms will not be needed, and again, such as deep learning algorithms, the system will not be overheated or the computer system will be locked.

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