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Region Extraction & Disease Recognition in MRI

— MRI 영상에서 영역추출과 질환인식 —

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— 국문요약 —

MRI imaging is one of the imaging techniques showing anatomical structures of human body for medical diagnosis, and has been researched in order to provide better quality of anatomical information. In this study, we propose a very useful method to extract an interest areas and how to diagnose necrolysis of femoral neck disease automatically. Regions of femoral neck is set using anatomical features and Hough transform and advantages of both region extension and histogram-based region segmentation method are combined for better region segmentation. As a result of the proposed method, good imaging quality was obtained for femoral neck with both normal and severe necrosis as well as for femoral neck in early stage of necrolysis.

Key Words : MRI, Automatic diagnosis, Hough transform, Region Extraction, Disease Recognition

I. Introduction

Up-to-date medical imaging systems providing visual information of internal structure have been developed thanks to the development of science and engineering. CR(computed radiography), CT(computed tomography), MRI(Magnetic Resonance Imaging) and PET(Positron-Emission Tomography) are typical medical imaging devices these days[1,2].

Of these imaging systems, MRI provides very exact information of general anatomical states of patients compared to other medical images[3]. As a result, MRI can diagnose diseases which are difficult to diagnose by other medical imaging systems, and has been used when anatomical states of patients should be examined more exactly. In addition, Researches have been developed on 3D restructuring for good quality of images from MRI and automatic recognition of diseases, of which images of brain and heart have been main targets and images of other organs have been new subjects of research[3-5].

However, when MRI is processed and recognized, it may cause difficulties due to its internal features: First, even the same tissue may show different brightness depending on its position and physical factors on its parts. Second, when a image is processed, fixed area of actual tissues is averaged and image is produced and brightness of each pixel can no more be information of tissues existing in actual position[6].

This study overcomes difficulties in processing MRI from images photographing regions of femoral neck and suggests extraction and segmentation methods of regions suitable to auto diagnosis of

necrolysis of femoral neck.

Region segmentation has been researched most in the area of imaging process[7]. But, there is no method that can be suitable to all images and good results can be obtained when features of a given input image are reflected well. Therefore, this study suggests region segmentation method combining *histogram-based region segmentation and region* extension as region segmentation method reflecting features of MRI, anatomical features of femoral neck and knowledge of necrolysis of femoral neck well.

Histogram-based region segmentation method makes histogram with given images, decides critical values and divides images into object and background as *the most general and frequently used segmentation* method[8]. Histogram-based region segmentation method has advantages of segmenting images globally. However, since this method depends on the shape of histogram, results of region segmentation are not exact when the shape of histogram is not suitable to decide critical values. So many researches on how to decide critical values using histogram have been developed[9].

Region extension means the process of integrating sets or subregions of pixels having similar properties[10]. Region extension can obtain good results when object to be segmented in image is shown as one in a specific region. However, regions of femoral neck have several problems because there are many areas of bone depending on the degree of necrosis.

Combining the advantages of the above two methods will achieve optimal region segmentation of regions of femoral neck. Since histogram-based region segmentation has the advantage of global segmentation of images and region extension has that of a single region segmentation, advantages of these two methods can be combined for deciding critical values of histogram-based methods using application results of region extension.

Ⅱ. Materials and Methods

1. Setting Regions of Femoral neck

To segment regions of femoral neck effectively, first expected region of femoral neck should be decided because the region of original femoral neck which was lost by necrosis is forecasted and it should be used for diagnosis of necrolysis of femoral neck.

To examine regions of femoral neck on T1 highlight image, hip joint between femoral neck and hipbone is shown dark. This is always found regardless of necrosis of femoral neck and is shown as almost circular shape. Therefore, the inside of this region can be assumed as the region of femoral neck and circle including regions of femoral neck with Hough transform can be found.

Searching circle with Hough transform can be divided into two steps : the first step is searching for the center of circle and the second one is deciding radius of circle[11].

First, in the step of searching the center of circle, there is normal vector at each point above the circle and this vector meets at the center of the circle. Normal vector regarded as the point of border from image to object can be assumed with regional gray-level edge operation like Sobel operator.

With application of edge operator, normal vector can be obtained at that point and straight line passing through the point with slope of normal vector can be obtained. After getting straight line of each point of images with the same method, point that many straight lines intersect will be the center of circle.

Second, in the step of deciding radius, histogram of radius is obtained by assigning center from equation of circle and then maximum value of histogram will be radius.

In general, imaging photographing region of femoral neck shows that region of femoral neck is always at similar position. Therefore, square including bone neck per each plane from input images can be caught with easy method and applying Hough

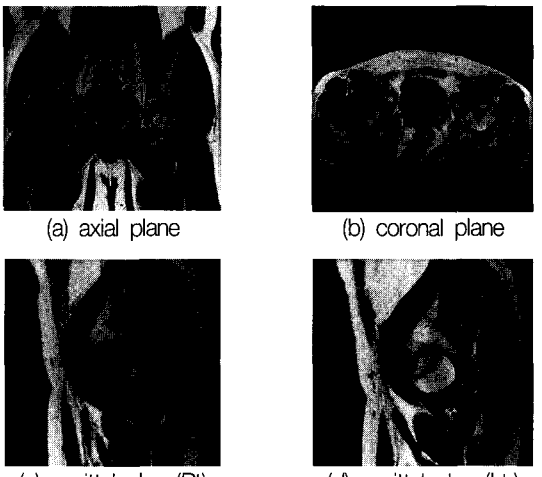

Fig. 1. MRI images of Femur

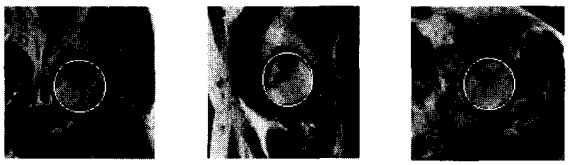

Fig. 2. Results of Extracting Region of Right femoral neck

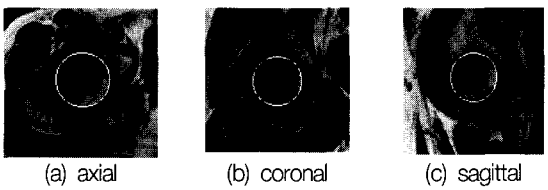

Fig. 3. Results of Extracting Region of Left femoral neck

transform within the square area will speed up and achieve better results.

However, circle searched through Hough transform doesn't always include femoral neck. In particular, in case of femoral neck with severe necrosis, it is difficult to include femoral neck since necrosis of femoral neck has very irregular shapes.

Therefore, obtaining circle with Hough transform, changing center (a, b) and radius r based on circle, setting a, b, r with the lowest mean pixel value and the greatest gradient as a new circle, and then the circle will indicate region of femoral neck. Points given by input when Hough transform is used are obtained by Sobel operator. Fig. 1 is an original MRI images used as input in this paper. Figures 2 and 3 are results of extracting regions of left and right femoral neck at input images and show circle including region of femoral neck.

2. Segmentation of Region of Femoral neck

1) Region Extension for Critical value

T1 highlight image in MRI is bright at a fatty part. There are several components in the bone of human body and in particular, since it has fatty matters, it is shown bright at T1 highlight image. And the part of bone necrosis is shown dark because there is no fat. Therefore this study uses critical value method to extract femoral neck from MRI. But, it is difficult to get exact critical values based on histogram shape. Therefore, advantages of histogram-based region segmentation are combined wit those of region extension and suitable region segmentation method is suggested to extract region of femoral neck.

Histogram-based region segmentation has advantages of global segmentation of images, but when the shape of histogram is not suitable to decide critical value, it is difficult to expect good results. According to histogram of region of femoral neck, it varies with the degree of necrosis and it is very difficult to decide critical value that discriminates bony part from non-bony part and thus, to obtain satisfactory results.

Region extension can obtain good results when an object to be segmented in image appears to be one. However, when it is used in segmenting regions of femoral neck, it is difficult to expect good results because the bony regions by degree of necrosis are irregular.

Combining histogram-based region segmentation for global segmentation of images and region extension method will achieve good results in segmentation of regions of femoral neck.

Bright part within region of femoral neck with circular shape shows remaining bone without necrosis and dark part is necrotic. Therefore, the most bright point within the region of femoral neck can be found at remaining bony part without necrosis. From this point, region extension is conducted and an area is obtained. There are two things to be decided for region extension : measure of similarity and conditions to finish region extension. The measure of similarity is based on gap between mean brightness of established region and the brightness of pixel under consideration and when this gap is less than critical value T, it is included in the region and when it is larger than critical value T, it is not included in the region. Also the conditions to finish region extension should bo no pixel to develop region extension any more. It is shown with pseudo code as follows.

```
R = {seed point}
repeat
 for each outer boundary pixel p of R
    if (average intensity of all pixels in R) - p < T
    then R = R ∪ {p}
    else next pixel
until no more pixel added to R
```

where, R at pseudo code is the region of progress of region extension and T is critical value indicating measure of similarity. T should be different according to input image because image of large contrast within region of femoral neck has broad range of pixel value to be considered bone and the image of small contrast has narrow range of pixel value to be considered bone. That is, when degree of necrosis of femoral neck is small or there is no necrosis, pixel value of starting point is relatively larger and contrast within femoral neck is great and when necrosis of femoral neck is severe, pixel value of starting point is relatively small and contrast is small within region of femoral beck.

Feature values indicating contrast of given images are varied and contrast of variance of brightness in a given image is usually used. This study sets contrast of region femoral neck as the brightest value in region of femoral neck. Then T value is decided by the following equation (2).

$$T = \frac{(\text{Max Intensity})^2}{C} \quad C : constant \qquad \cdots\cdots\cdots (2)$$

Histogram of resulting region from region extraction has the shape of convex on the middle and symmetry on the left and right and shows similar distribution to normal one. So this histogram can be defined as normal distribution.

Normal distribution is decided by mean (m) and standard deviation (σ) and mean (m) and variance (σ^2) of a given histogram is shown in Equation (3) and $H(i)$ is a given histogram.

$$m = \frac{\sum_{i=0}^{255} i \cdot H(i)}{\sum_{i=0}^{255} H(i)} \quad \sigma^2 = \frac{\sum_{i=0}^{255} (i-m)^2 \cdot H(i)}{\sum_{i=0}^{255} H(i)} \qquad \cdots\cdots\cdots (3)$$

And, position from the center to left of normal distribution curve can be set as critical value.

This study sets $m-3\sigma$ which is 0.1% from 0.2% of normal distribution curve as critical value.

2) Complement of Region Segmentation

Methods suggested at the foregoing paragraph can obtain good region segmentation results of contrast with images of severe necrosis. The reason bone is bright in T1 highlight image is that it contains fat and its center is dark because it contains less fat than its edge due to pressures. Normal image and image in early stage of necrosis have little influence on region segmentation, but severe necrosis reduces fat due to necrosis except for the case of under-pressure, and results of region segmentation are getting worse. Because results of region extension are biased toward bright edge, critical value is larger than that desired. Also when necrosis is developed more, critical value cannot be less than the whole average brightness because bright part is less and dark region is more.


(a) Results of region segmentation


(b) Complementary region segmentation

Fig. 4. Region Segmentation of Severe Necrosis (Fig. 3 (b))


(a) axial


(b) coronal


(c) sagittal

Fig. 5. Region Segmentation Results of Right femoral neck

Therefore, as shown in equation (4), when degree at the center of region from region extension is examined and critical value is moved to the whole average brightness value, better results can be obtained. Fig. 4 indicates results using methods for Fig. 3 (b) and complementary region segmentation.

$$T_{new} = T_{old} - k \cdot \frac{R_{center}}{R_{all}} \cdot (T_{old} - I_{ave}) \quad \cdots\cdots\cdots (4)$$

T_{old} : Obtained Th
T_{new} : New Th
R_{all} : Result area of extended area
R_{center} : Include area into center among result area
I_{ave} : Average brightness of femoral neck region
k : *Constant*

III. Result & Discussion

Fig. 5 and 6 show region segmentation results within femoral neck of Fig. 2 and 3. And Table 1 is the accuracy of region segmentation results of images of femoral neck by plane. Accuracy of region segmentation results is obtained by comparing results of the methods proposed in this study to those of manual region segmentation by those who have professional knowledge of necrolysis of femoral neck. Ratio of the number of the whole pixel to the same pixel in two resulting images was considered as the accuracy of region segmentation and it is the mean value of images of femoral neck


(a) axial


(b) coronal


(c) sagittal

Fig. 6. Region Segmentation Results of Left femoral neck

Table 1. Accuracy of Region Segmentation Results

	axial	coronal	sagittal
Right femoral neck	96%	95%	97%
Left femoral neck	94%	93%	96%

photographed sequentially on each plan. According to Table 1, each has accuracy over 90% and right femoral neck with weak necrosis has relatively higher accuracy and images of sagittal plane have higher accuracy.

IV. Conclusions

This study suggests region extraction methods suitable to diagnosis of necrolysis of femoral neck in MRI.

Region set method suggested in this study uses anatomical characteristics of femoral neck. It uses characteristics unrelated to absence or presence of necrosis of femoral neck and hip joint between hipbone and femoral neck appears to be dark in T1 highlight image and shape of femoral neck is similar to circle.

And region segmentation method combines advantages of existing histogram-based method and region extention method to be suitable for diagnosis of necrolysis of femoral neck and it is applicable regardless of degree of necrosis.

Since region of femoral neck extracted by this study has high accuracy as shown in the foregoing experimental results, it can be used as a good input for the auto diagnosis of necrolysis of femoral neck.

Future researches must focus on obtaining better results when severe necrosis brings about deformation of bone neck shape and treating many irregular shapes on the image photographing edge of bone neck in effective ways. Introduction of knowledge on exact pathophysiology and pathogenesis can establish professional system for auto diagnosis and prognosis of necrolysis of femoral neck.

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• Abstract

MRI 영상에서 영역추출과 질환인식

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인체의 해부학적 구조에 관해 다른 영상들보다 정확한 정보를 제공하는 MRI에 대해 많은 연구가 진행중이다. 본 논문에서는 대퇴골두 무혈성 괴사의 자동 진단에 필요한 대퇴골두 영역의 추출에 관한 효과적인 방법을 제안한다. 대퇴골두의 해부학적 특성과 Hough transform을 이용하여 대퇴골두 영역을 설정하였고, 대퇴골두 영역을 분할하는 방법으로서 영역 확장법과 히스토그램 기반 영역 분할 방법의 장점을 결합한 방법을 고안하였다. 본 논문에서 제시한 방법은 정상적인 대퇴골두와 무혈성 괴사의 초기 단계의 대퇴골두 뿐만 아니라 괴사가 심한 대퇴골두에 대해서도 좋은 결과를 얻을 수 있었다.