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IMAGE SEGMENTATION: DETERMINATION OF JOINT SPACE AREA INHAND RADIOGRAPHS

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ABSTRACT

This paper is an attempt to investigate the possibility of automating assessment of joint damage in hand radiographs. The goal is to design a segmentation algorithm to obtain the area which is an object, the joint space. Image segmentation is the process of partitioning a digital image into several segments. For this study has collected 46 hands radiographic images. Pre-processing done using adaptive threshold and morphological gradient concept, then do segmentation with watershed transformation. Analysis results of segmentation based on the level of accuracy, sensitivity and specificity using the ROC. Results of segmentation with pre-processing, produces images that are not over-segmentation and produces a clearer image with accuracy value of 95.75%, sensitivity of 70.51% and specificity of 96.99% in a high percentage.

Keywords: hand radiograph, preprocessing, segmentation, joint space.

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic inflammatory disease that causes pain, swelling, stiffness and loss of joint function [1]. This disease usually affects the joints, especially in the wrist and fingers.

Radiography is the imaging modality that is most widely used to measure joint damage in early RA [2]. Assessment of radiographic joint damage to the hand is a method often used to monitor the development of RA. Some of the proposed scoring method is based on measuring the ratio of carpal/metacarpal, joint space width, volume erosion and damage classification [3,4] In general, this method is time-consuming and subjective measurement results.

In this paper, image processing is done in an effort to equalize the perception of the observer to read pictures. In image processing, there is an important process that is often used as an initial processing that is then used in another process of segmentation. One technique based image segmentation region used in this study is the process of segmentation is done to get the area that is believed to be an object [5]. To get the area, analyzing the similarity of texture and color of the pixels is contained in the image. This study presents a segmentation algorithm capable of identifying a joint space, which is based on regional segmentation using watershed transformation [6,7] This is a segmentation method contains information about how to determine the dividing line between objects into the background. This model is useful in cases where there is joint damage (Figure 1). Because of the severity of the erosion of the joint space is not visible even be lost, it is difficult to identify the location of joints with ordinary image processing techniques. With watershed transformation algorithm can be determined borderline object (area) is important so that the site can be estimated accurately enough to get the area which is the object to be segmented [8]. The final goal of this research is to develop automated assessment procedures with a higher sensitivity compared to manual measurement.

Previous research on segmentation using watershed transformation has been described in [9] and [10]. In this study, the watershed transformation algorithm used to determine the boundary area of joint space hand radiographs of patients with RA.

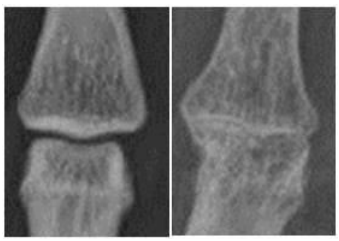

Figure-1. Joint damage that occurs in patients with AR: PIP II is a healthy joint (left) with joint space are visible and PIP II faulty joint (right).

MATERIALS AND METHODS

Materials: Forty-six radiographic images right and left hand of the patient AR in a single model. The study design was approved by the Ethics Committee of the Faculty of Medicine, UB and informed consent were obtained from all subjects. The images used for this study, is a digital image of plain radiographs in .JPG with dimensions of 1760x1760. X-ray tube is set to taking pictures with size of FFD 100cm; 65 kV; 125 mA; 0.080 sec.

Methods: To segmentation radiographic hand we are interested in finding the location and contours of the

joint. For this purpose, we use a watershed transformation with previously doing the initial processing. Initial processing is the process of making certain areas (cropping) to be observed (area of interest) to reinforce the border to be processed and avoid the analysis beyond the study area. After cropping, the dimension of each part is 256x256 pixels. Before the image undergoes further processing, pre-processing is necessary to image processing to obtain an image with a pattern that may be encoded, using adaptive threshold and convolution using a median filter. Hand radiograph images are used in the form of grayscale. Furthermore, the concept of a morphological gradient for image extraction step is done before the segmentation process to reduce over-segmentation can occur, so that watershed transformation can produce good segmentation results. The process of image segmentation with watershed transformation is done to get the area believed to be an object, in this case the joint gap. Segmentation results were analyzed based on the level of accuracy, sensitivity and specificity using the ROC (Receiver Operating Characteristic).

Pre-processing

Radiographic images in the training set, containing pictures right and left hand, so that both hands can be used for training a single model.

Figure-2. Models of hand radiographs were used in the experiment.

Hand radiographs is a two-dimensional projection of a collection of three-dimensional, making it possible that portions of certain bones overlap one another. To overcome the effects of a hand model is necessary to separate the model in to sub-models by way of cropping.

Adaptive threshold

Threshold is used to form a binary. Adaptive threshold can be termed as a different threshold when the threshold used for different regions in the image. Usually, the object pixel rated 1 pixel background rated 0. In the end a binary image formed by the color of each pixel with a white or black depending on the label of the pixel.

Convolution methods

Convolution is very useful for screening operations (filtering) on the image. In the digital image processing, convolution performed in two dimensions of an image, as shown by the equation:

$$g(x,y) = f(x,y) * h(x,y) = \sum_{\alpha=-x}^{\infty} \sum_{b=-x}^{\infty} f(a,b)h(x-a,y-b) \quad (1)$$

Where f(x,y) is the original image, h(x,y) is the convolution matrix, g(x,y) is the image of the convolution.

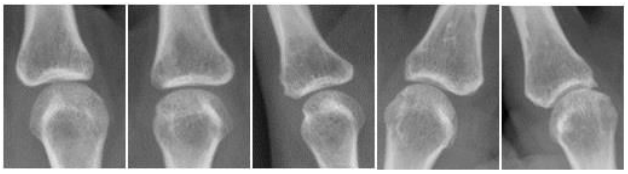

Figure-3. Sub-models for experiment. Left to right: MCP III (right hand), MCP IV (left hand), MCP V (left hand), MCP II (left hand), MCP II (right hand).

Median filter

The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise.

Pre-segmentation

Morphological gradient

Morphological image is an image-processing operation that processes the image based on its shape. Morphological gradient is a process that produces an output in the form of an image obtained from the reduction of the original image dilation results with the results of the erosion of the original image, so it can be defined:

$$g = (f \oplus b) - (f \ominus b) \quad (2)$$

Dilation operations performed by the way, A and B is set on the set Z2 and ∅ declare an empty set, dilation of A by B is expressed by A ⊕ B, and is defined as:

$$A \oplus B = \{x|(B')_x \cap A \neq \emptyset\} \quad (3)$$

B' is the reflection of B, then the dilation process consists of the process of looking for a reflection of B on the origin and the reflection shifts as x.

Erosion is a process whereby if there is A and B which is set the set Z2, erosion of A by B is denoted by A Θ B, and is formulated as:

$$A \ominus B = \{x|(B)_x \subseteq A\} \quad (4)$$

Besides morphological gradient, other pre-processing is used before the transformation is opening and closing. Opening is a process that does erosion followed by dilation as shown in the formula below:

$$A \circ B = (A \ominus B) \oplus B \quad (5)$$

Closing is a process that performs a dilation followed by erosion.

$$A \cdot B = (A \oplus B) \ominus B \quad (6)$$

Segmentation

Watershed transforms

Concepts contained in this watershed visualize an image in three dimensions: two spatial coordinates versus gray level. The spatial coordinates x and y position on a flat and gray level is an altitude, the direction of the white color, the height increases.

The essence of the method of determining the watershed line, the dividing line between objects in the background. The formation of watershed or dam line is based on the binary image, which is a member of the two-dimensional integer space Z2. The easiest way to build a dam is by using morphological dilation operation.

Identification of high distinction will be stored in the output pixels associated with a starting point. When all the pixels in the image have been compiled with the respective minimum value, the output image will contain a watershed region of the image. Boundary of the watershed region associated with the highest intensity regions of the image.

RESULTS AND DISCUSSIONS

Results of the application segmentation with watershed transformation method treated with pre-processing and pre-segmentation can reduce over-segmentation quite significant. This can be demonstrated by comparing the results of segmentation watershed transformation without treatment with watershed transformation segmentation results with the treatment. Segmentation method of performance testing conducted to see how well the method is applied to analyse the test results using the ROC [12] by comparing the results of the segmentation system with manual segmentation results to measure accuracy, sensitivity, and specificity.

In the Figure-4, seen happen over-segmentation, so the results are less clear segmentation. Figure-5 shows that the over-segmentation reduced, so that the segmentation results can be viewed more clearly.

Table-1 shows the average calculation using the ROC, which in the calculation of image segmentation using watershed transformation without preceded by pre-processing and pre-segmentation compared with manual segmentation results.

Figure-4. Results of watershed transformation without treatment (morphological gradient).

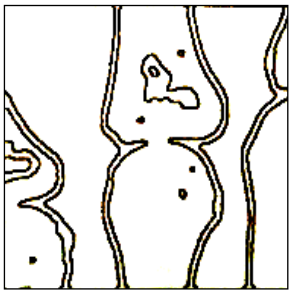

Figure-5. Results of a watershed transformation with the treatment of the morphological gradient.

Table-1. The average value calculation segmentation of the untreated comparison of some sub-models.

Name of joint	Accuracy (%)	Sensitivity (%)	Specificity (%)
IP I	6.84	3.32	9.15
PIP II	6.71	5.28	7.87
PIP III	5.89	6.25	6.94
PIP IV	6.62	6.09	7.34
PIP V	6.27	5.26	7.14
MCP I	8.20	9.33	6.98
MCP II	11.98	8.78	14.29
MCP III	17.49	13.32	20.14
MCP IV	6.96	12.05	20.15
MCP V	9.61	7.08	11.59

Based on the calculation that the system has the ability to image segmentation of each joint space is not good. Of the value of the test indicated a very low percentage of the maximum value of the accuracy 17.49%, sensitivity 13.32% and specificity 20.15%.

Results of the experiments are shown from several sub-models training set image radiography left and right hands, each of which consists of 10 parts of the joint space, namely IP I, PIP II, PIP III, PIP IV, PIP V, MCP I, MCP II, MCP III, MCP IV, MCP V in two output image

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pre-processing with adaptive threshold, watershed transformation segmentation with morphological gradient.

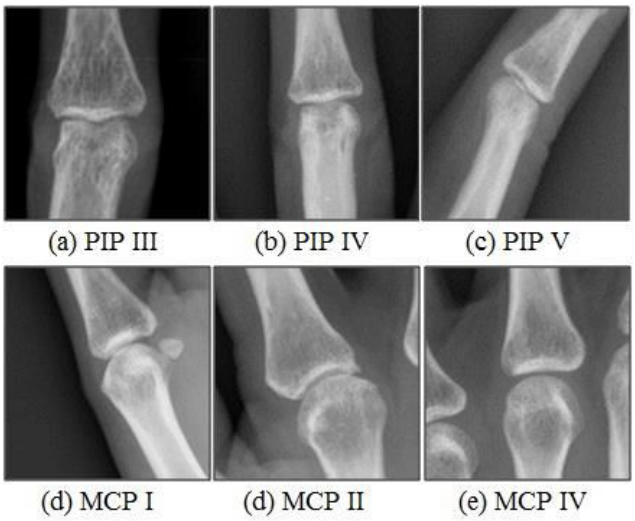

Figure-6. Original image.

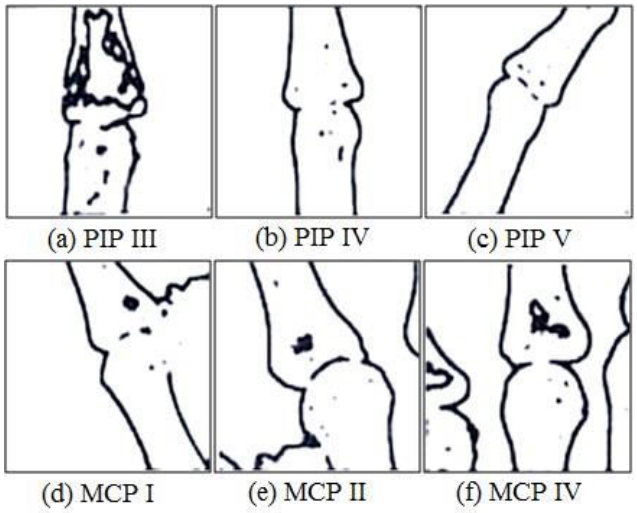

Figure-7. Result of pre-processing with adaptive threshold and median filter.

Table-2 shows the average calculation using the ROC, which in the calculation of image segmentation using watershed transformation with pre-processing and pre-segmentation compared with manual segmentation results.

Based on the calculation that the system having an image segmentation capability of each joint space with very good when compared to the percentage calculation without any treatment of the image. Of the value of the test indicated high percentage with an accuracy 95.75%, sensitivity 70.51% and specificity 96.99%. The lowest percentage value testing with accuracy 77.54%, sensitivity 51.47%, and specificity 88.18%.

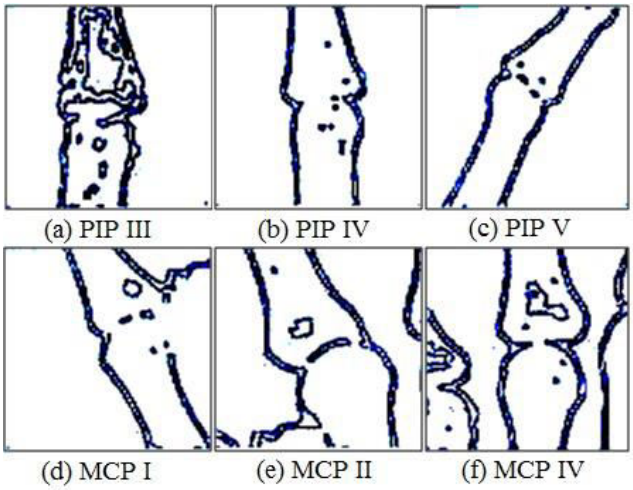

Figure-8. Result of watershed transformation segmentation with morphological gradient.

Table-2. The average value of calculation segmentation comparison with the behavior of some sub-models.

Name of joint	Accuracy (%)	Sensitivity (%)	Specificity (%)
IP I	94.03	69.45	94.99
PIP II	94.87	62.05	95.96
PIP III	95.44	57.81	96.74
PIP IV	95.41	59.67	96.59
PIP V	95.75	59.91	96.99
MCP I	94.99	51.47	96.77
MCP II	77.54	62.93	92.57
MCP III	87.43	67.94	88.94
MCP IV	86.63	70.51	88.18
MCP V	92.16	64.00	93.29

CONCLUSIONS

Results can be obtained from this study is that by using the watershed transformation, the result of segmentation in the form of the object to the desired area. Results of the watershed transformation have a tendency to produce excessive segmentation, so that the necessary pre-processing. The initial processes using adaptive threshold and the concept of a morphological gradient prior to the segmentation process with watershed transformation are to produce images that are not over-segmentation and produces a clearer image.

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