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Crack detection in X-ray images using fuzzy index measure

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ABSTRACT

Crack of the bone is a very serious medical condition. In medical applications, sensitivity in detecting medical problems and accuracy of detection are often in conflict. Computer detection of cracks can assist the doctors by flagging suspicious cases for closer examinations and thus improve the timeliness and accuracy. This paper presents the detailed image processing procedure including the grid formation, local thresholding, threshold value interpolation, segmentation using fuzzy index measure, background removal, and morphological filtering for the determination of infestation sites of a crack in X-ray image. The image processing procedure was tested with X-ray images of several types of crack bones. Additional tests and analyses were also performed using the developed algorithm on the X-ray images obtained with different image acquisition parameter. Compared to existing methods, this approach enhances the accuracy and reliability of proposed work.

1. Introduction

In medical applications, sensitivity in detecting medical problems and accuracy of the detection (also called specificity) are two important performance measures that are often in conflict. Computer detection of cracks can assist the doctors by flagging suspicious cases for closer examinations and directing the doctor's attention to suspicious cases. It can thus improve the timeliness and accuracy of their diagnosis. Computer detection of cracks in X-ray images is a difficult and challenging problem. The femur can crack in many ways with varying degrees of severity. While severe fractures cause drastic change to the shape of the femur, mild fractures do not change the femur's shape and leave only very subtle signs in the X-ray images

Tian et al. [2] published the first research work on the detection of fractures in X-ray images by computing the angle between the neck axis and shaft axis. Subsequently, Lim et al. [3] Yap et al. [4] and Lum et al. [5] reported methods detect femur fractures based on Gabor, Markov Random Field, and gradient intensity features extracted from the X-ray images. Three SVMs were trained to classify the samples each based on a different feature type. The individual SVM's performance was not very good. By combining the decisions of the three SVMs, the overall accuracy and sensitivity (i.e., fracture detection rate) were improved.

There are lots of image segmentation techniques in the literature, which can be broadly classified into two categories namely: (i) classical [7–10] and (ii) fuzzy mathematical [11]. The former contains five main classes (i) Gray level thresholding [12], (ii) iterative pixel classification [13–15], (iii) surface-based segmentation [16], (iv) colour segmentation [17], and (v) edge detection [18]. The fuzzy mathematical techniques [25] are broadly classified into six categories: (i) Fuzzy geometric, (ii) fuzzy thresholding, (iii) fuzzy integral-based, (iv) fuzzy rule-based, (v) soft computing-based and (vi) fuzzy clustering. Apart from these two groups, there are varies of image segmentation techniques which are based upon Markov random models, the Gibbs distribution and Bayesian principles [14,19].

The fuzzy region growing segmentation algorithm groups pixels into larger regions in which the homogeneity criterion hold. The complete fuzzy region growing segmentation procedure makes use of the fuzzy regions grows from different seeds to complete the automated image segmentation [20].

The bone damage was assessed from the X-ray CT imaging using non-linear resonant ultrasound spectroscopy helps to get the prominent cracks in the bones [21]. The modified Watershed segmentation approach and small scanning window are applied in X-ray image to detect the lung cancer and tuberculosis [22]. The atlas-based approach for automatic segmentation of femurs in X-ray images will produce the consistent sets of edge segments registers the whole atlas to the image under joint constraints [23]. A novel cracking automatic detection approach based on segment extending for complex pavement images proposed to identify cracks correctly and entirely [24].

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The prediction methodology of finite-element analysis (FEA) based on J-integral value estimation is used to investigate the interfacial fracture opportunity of low-k packages. Various paths with an integral contour surrounding the crack tip are considered to avoid a misunderstanding of the cracking energy [26]. The accuracy assessment for object based image segmentation is analyzed using different objects. The measures are shown to be an intuitive, useful technique for consistency checking different segmentation results and assessing segmentation accuracies among a large set of disparate segmentation results [27]. A fatigue crack growth prediction of surface cracks in plates under a combined tension and bending load. A re-meshing technique developed enables the procedure to be implemented automatically, and then fatigue crack growth can be predicted in a step-by-step way [28]. Thus, in this paper, we choose to fuzzy index measure to detect cracks in X-ray images.

2. Proposed scheme for detecting cracks

To satisfy the need of the crack detection in the bone, we proposed an algorithm for finding the optimal thresholds for segmenting gray scale images. The initial estimates of the parameters of the fuzzy subsets derived from the histogram then uses fuzzy entropy as cost measure to maximize the similarity between pixels of the same subset and.

The background of the X-ray image segmentation and the crack detection will be expressed in the second section. The recent and previous works carried out in this area are produced in third section. The fourth section produced the proposed algorithm and the method of approaches. The implementation, experimental procedures and the results are discussed in the fifth section. This also point out the efficiency of the proposed method. This paper concludes with lot of proposals and the future challenges of the approach.

2.1. Fuzzy set theory

Any segmented image will produce fuzzy regions. The fuzzy-based image segmentation techniques will be an attractive and effective approach for handling imprecise image information by employing fuzzy membership functions. The gray levels of an image I with size $M \times N$ having the range from 0 to $2^n - 1$ can be defined as an array of fuzzy membership, which can be represented by

$$I = \{\mu_x(x_{ij}), \quad i = 1, 2, \ldots, M \text{ and } j = 1, 2, \ldots, N\} \tag{1}$$

where $\mu_x(x_{ij})$ denotes the fuzzy [6] grade of brightness of pixel located at (i,j).

The fuzzy sets theory is useful to consider the images as fuzzy subsets of a plane. The gray level at a given pixel position can be interpreted as the degree of member. A fuzzy set F is a subset of the universal set I that admits partial memberships, which can be defined as

$$F = \left\{x_{ij}, \mu_F(x_{ij})\right\} \tag{2}$$

where $x_{ij} \in I$ and $0 \leq \mu_F(x_{ij}) \leq 1$.

If x_{ij} is a member of I then $\mu_F(x_{ij})$ is equal to one, otherwise $\mu_F(x_{ij})$ is equal to zero. To characterize Fuzzy set F we can use several types of membership functions. The generalized bell membership function defined as

$$\mu_F(x_{ij}) = \frac{1}{1+y} \tag{3}$$

where $y = |(x_{ij} - c)/a|^{2b}$, a is the width of the set at the cross over point, b is the slope of the curve and c is the center of the membership function.

The fuzzy entropy is a measure of fuzziness that becomes smaller when the similarity of its argument is increased. This is used to measure degree of fuzziness of a subset. There are several types of measures proposed in the literature. The most common type of measure is Shannon's entropy [1] and is defined as,

$$E = -\sum_k {S_k}^2 \log({S_k}^2) \tag{4}$$

where S_k is the coefficient sample within the given sub-band.

Another commonly used method is distance measure [2], which is based on the distance between fuzzy subset F and its complement subset F^c. The index of fuzziness based on the distance between F and its complement set is defined as

$$I(F) = \frac{2}{(N \times M)^{1/n}} d_n(F, F^c) \tag{5}$$

where n is the order of the distance used and the distance between the two sets

$$d_n(F, F^c) = \left\{ \sum_{i=1}^{N} \sum_{j=1}^{M} \left[\mu_F(x_{ij}) - \mu_{F^c}(x_{ij})\right] \right\}^{1/k} \tag{6}$$

The fuzzy index measure is used to find out the amount of confusion between pixels in an image. It measures the ambiguity of the fuzzy subset or the homogeneity between pixels of the set. It can be used as a cost term in a minimization process in order to reduce the confusion between pixels in subsets. These subsets are constructed by forcing the pixels to be in the subset that minimizes the fuzzy index.

The overall block diagram is shown in Fig. 1.

2.2. Adaptive thresholding algorithm

The major purpose of adaptive thresholding is to give each pixel a suitable threshold value that is dependent on the distribution of gray levels of the neighborhood pixels. To achieve this, we create a map of threshold values which has the same size with the original

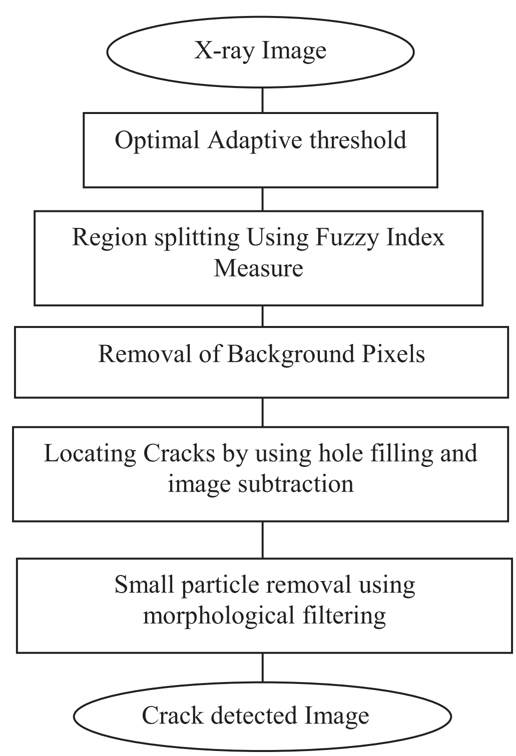

Fig. 1. Block diagram of proposed method.