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Bone Age Assessment using Wavelet Transform

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Abstract: ***The present paper proposed a new method of computer aided diagnosis of bone age assessment (BAA) using wavelet transforms. For this, the edge detection using wavelets is performed and different features are measured. Based on these measures the BAA has performed. The database of bone images for this experiment is taken from Digital Hand Atlas of the Image Processing and Informatics lab. By this computer aided diagnosis using wavelet transforms will lead to a revolutionary, innovative and cost-effective computer aided diagnosis method for real*** **time automatic bone age assessment to assist radiologist in medical field**.

***Keywords**: Wavelet Transform, Bone Age Assessment, Edge Detection.*

1. Introduction

The wavelet analysis can be interpreted as image decomposition in a set of independent, spatially oriented frequency channels. There are various wavelet transforms like Haar, Daubechies, Coiflet, Symlet and etc. They differ with each other in the formation and reconstruction. All the wavelet transformed images are divided into four subbands and they are denoted by LL(low-low), LH(low-high), HL(high-low) and HH(high-high) frequency subbands. The HH subimage represents diagonal details (high frequencies in both directions – the corners), HL gives horizontal high frequencies (vertical edges), LH gives vertical high frequencies (horizontal edges), and the image LL corresponds to the lowest frequencies. At the subsequent scale of analysis, the image LL undergoes the decomposition using the same filters, having always the lowest frequency component located in the upper left corner of the image. Each stage of the analysis produces next four subimages whose size is reduced twice when compared to the previous scale. i.e. for level '*n*' we get a total of '4+(n-1)*3' subbands. The size of the wavelet representation is same as the size of the original. The Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function which generates an orthogonal multiresolution analysis.

Today, it is generally accepted that multiresolution approaches are extremely important in many signal and image processing applications. This is largely due to the fact that signals (and images in particular) often contain physically relevant features at different scales or resolutions. For a proper understanding of such signals, multiresolution (or multiscale) techniques are indispensable. But there exist other good reasons for taking recourse to multiresolution approaches. A major one is that multiresolution algorithms may offer some attractive computational advantages.

Bone age assessment (BAA) is a clinical procedure frequently performed in pediatric radiology to evaluate the stage of skeletal maturation based on a left hand and wrist radiograph. The determination of bone age plays an important role in diagnostic and therapeutic investigations of endocrine problems and growth disorders of children. For decades, the determination of bone maturity has relied on a visual evaluation of the skeletal development of the hand and wrist, most commonly using the Greulich and Pyle atlas.With the advent of digital imaging, multiple attempts have been made to develop image-processing techniques that automatically extract the key morphological features of ossification in the bones to provide a more effective and objective approach to skeletalmaturity assessments. However, the design of computer algorithms capable of automatically rendering bone age has been impeded by the complexity of evaluating the wide variations in bone mineralization tempo, shape and size encompassed in the large number of ossification centers in the hand and wrist. Clearly, developing an accurate digital reference that integrates the quantitative morphological traits associated with the different degrees of skeletal maturation of 21 tubular bones in the hand and 8 carpal bones in the wrist is not an easy task.

During the past fifteen years, the Image Processing and Informatics Lab have developed a digital hand atlas (DHA) with 1,400 hand images of normal children, male and female from Asian, African American, Caucasian and Hispanic descent collected at the Children's Hospital Los Angeles (CHLA) funded by NIH; and a fully automatic and robust computer-aided-diagnosis (CAD) method adapted to these four populations and two genders. With DHA and CAD method in the clinical environment as a useful tool, the future BAA workflow is shown in Figure 1.

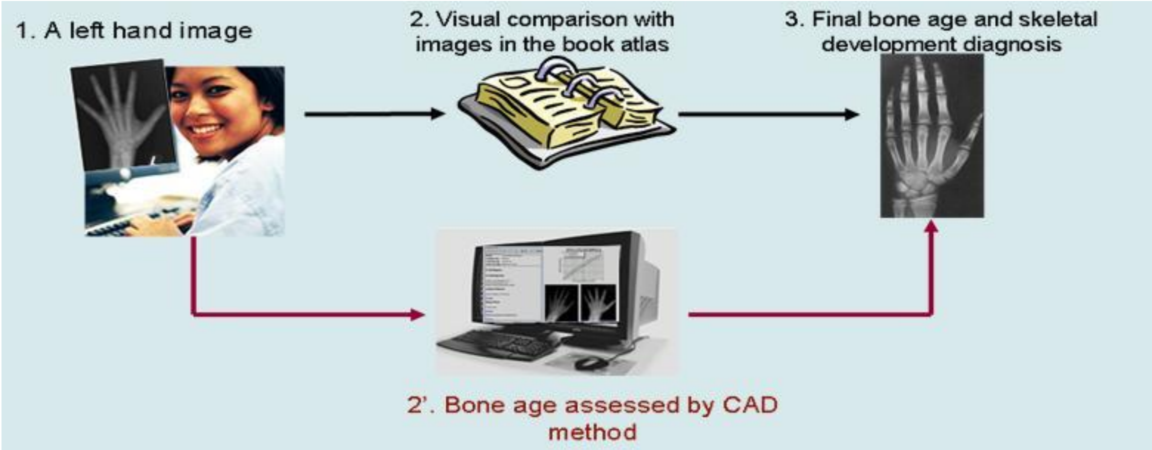

Figure 1. The ideal scenario of bone age assessment.

A total of 1,400 left hand and wrist radiographs of normal children, along with patients' demographic data and radiologists' readings were collected from Childrens Hospital Los Angeles, distributed in 19 groups (newborn, 1-18) of eight categories (i.e. Caucasian, African-American, Hispanic, and Asian), both male and female. A computer-aided-diagnosis method has been developed to determine the bone age based on two regions: phalangeal and carpal bone regions from each image. The integration of the third region: wrist joint is under development. (Figure 2) .

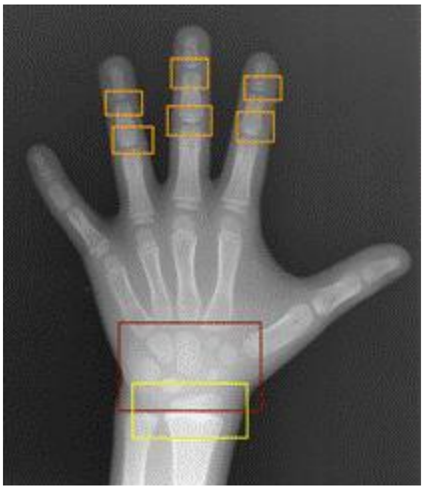

Figure 2:An example left hand

Figure 2. An example left hand and wrist radiograph with super-imposed regions of interest.

Collaborating with Dr. Linda Vachon, chief of pediatric radiology at Los Angeles County Women's and Children's Hospital (LAC WCH), we are in implementation of the CAD system in clinical daily practice. Referring to Figure 3, the current clinical workflow of the BAA at LAC WCH is as follows: 1) Hand X-ray from the CR (Computed Radiography) modality is sent to PACS workstation (WS) where radiologists review images and perform BAA (Figure 3 upper dotted box). In the clinical implementation of the BAA CAD system, the additional workflow is as follows:

2) A second copy of image from radiology department is sent to the CAD server located at IPILAB.

3) The CAD BAA report will be available in 2-3 minutes for radiologists at LAC WCH to review; 4) The radiologist who reviewed this case will perform a second assessment which is captured and will be sent back to the server for tabulation and statistical analysis.

2. Methodology

In this paper, we have developed a technique of Bone Age Assessment (BAA) using Haar wavelet Transform. The Haar wavelet is the first known wavelet and was proposed in 1909 by Alfred Haar [1, 2, 3]. Haar used the following functions to give an example of a countable orthonormal system for the space of square-integrable functions on the real line.

The Haar wavelet's scaling function $\varphi(t)$ can be described as

$$\phi(t) = \begin{cases} 1 & 0 \le t < 1, \\ 0 & otherwise. \end{cases} \quad (1)$$

and its wavelet function $\psi(t)$ can be described as

$$\psi(t) = \begin{cases} 1 & 0 \le t < 1/2, \\ -1 & 1/2 \le t < 1, \\ 0 & otherwise. \end{cases} \quad (2)$$

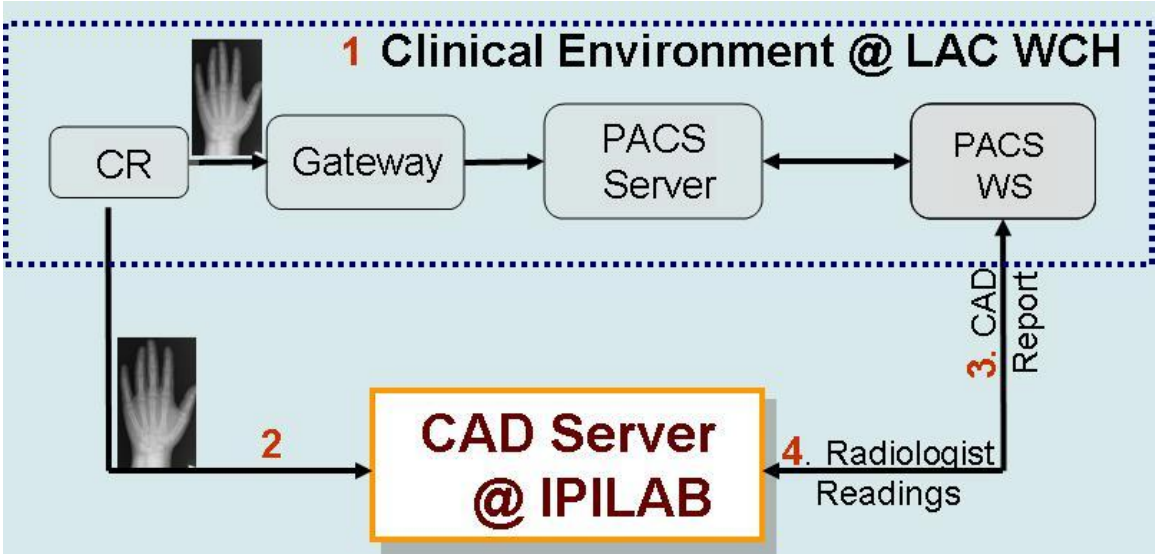

Figure 3. Workflow of CAD implementation at LAC WCH

The Haar transform is both separable and symmetric and can be expressed in matrix form

$$T = HFH \qquad (3)$$

where F is an $N \times N$ image matrix, H is an $N \times N$ transformation matrix, and T is the resulting $N \times N$ transform. For the Haar transform, transformation matrix H contains the Haar basis functions, $h_k(z)$. They are defined over the continuous, closed interval $z \in [0,1]$ for $k=0,1,2,3,\ldots N\text{-}1$, where $N=2^n$. To generate H, we define the integer k such that $k=2^p+q-1$, where $0 \le p \le n-1$, $q=0$ or 1 for $p=0$, and $1 \le q \le 2^p$ for $p \ne 0$. Then the Haar basis functions are

$$h_0(z) = h_{00}(z) = \frac{1}{\sqrt{N}}, z \in [0,1] \qquad (4)$$

and

$$h_k(z) = h_{pq}(z) = \frac{1}{\sqrt{N}} \begin{cases} 2^{p/2} & (q-1)/2^p \le z < (q-0.5)/2^p, \\ -2^{p/2} & (q-0.5)/2^p \le z < q/2^p, \\ 0 & otherwise, z \in [0,1] \end{cases} \qquad (5)$$

T

he i^{th} row of an $N \times N$ Haar transform matrix contains the elements of $h_i(z)$ for $z=0/N, 1/N, 2/N, \ldots (N\text{-}1)/N$. If $N=4$, for example, k, q and p assume the values as under

k	p	q
0	0	0
1	0	1
2	1	1
3	1	2

and the 4×4 transformation matrix H_4, is

$$H_4 = \frac{1}{\sqrt{4}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ \sqrt{2} & -\sqrt{2} & 0 & 0 \\ 0 & 0 & \sqrt{2} & -\sqrt{2} \end{bmatrix} \qquad (6)$$

In a similar manner, the 2×2 transformation matrix, H_2 is

$$H_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \qquad (7)$$

For 8×8, the transformation matrix, H_8 is

$$H_8 = \frac{1}{\sqrt{8}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ \sqrt{2} & \sqrt{2} & -\sqrt{2} & -\sqrt{2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sqrt{2} & \sqrt{2} & -\sqrt{2} & -\sqrt{2} \\ 2 & -2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 2 & -2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & -2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 2 & -2 \end{bmatrix}$$

In this way, it can be generated for any size of the image (generally in the powers of 2). The whole process of our method is given in the following algorithm.

Algorithm for the bone age assessment using wavelet transforms:
Begin
Step-1: Read the Original Bone Image.
Step-2: Apply the forward Wavelet Transform.
Step-3: Get the edge image by altering the wavelet transformed coefficients i.e., making the LL subband coefficients as 0s and apply the inverse wavelet transform.
Step-4: Extract the features.

Step-5: Compare the features with the Digital Hand Atlas (DHA) features.

Step-6: Get the final report.

End

3. Results and Discussions

The above algorithm is applied to some of the bone images taken from Image processing and Informatics Lab's DHA [4]. The original bone images are shown in Figure 4 (a). The wavelet transformed image is shown in Figure 4(b). The result of making all the LL band coefficients as zeros are shown in Figure 4(c). The result of the edge detection is shown in Figure 4(d).

4. Conclusions

The success of the clinical validation will lead to a revolutionary, innovative and cost-effective Computer aided diagnosis method for real-time automatic Bone age assessment to assist radiologists. Because of the multiresolution analysis capability of the wavelets, the results we get are good. By using wavelets for this, we accomplish remarkable performance and efficiency of this computer aided diagnosis.

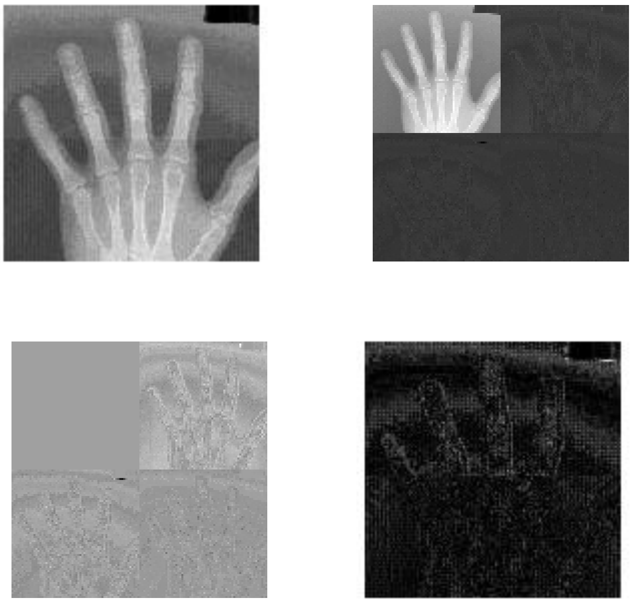

Figure 4. (a) Original Bone Image (b) Wavelet Transformed Image (c) Result after zeroing the LL coefficients. (d) Edge Image.

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