# Automatic Estimation of Skeletal Age Based on Prototypes of Hand Radiographs

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## 1 Introduction

The assessment of skeletal maturity is one of the important research topics in the field of paediatrics and growth diagnostics. In order to evaluate the skeletal maturity, bone age is used. Generally, radio-graphical images of the hand and wrist bones are used for estimation bone age. Because of it is not costly, reduction of radiation influence, and there are a lot of information for evaluation. The major method for evaluating the bone age is Tanner and Whitehouse method (TW2). In spite of its superior performance of the TW2 method to the other methods, it is not easy to get used to the method, and even for trained observer it takes a lot of time to evaluate a single radiogram. Hence, there has been a great deal of demand to develop a computerized automatic analysis of hand radiographs for the assessment of bone age.

Most of the researches for automatic analysis have focused on the two types which are, based on classify bones as the maturity stage defined in TW2, and detect contours of the bones to get the length and areas. This is because that the length and areas are thought to have some correlations with the bone age. However, we think these have some problems. The former, there is the possibility that the information lack caused by classification has a bad influence on the estimate precision, the latter, it is too difficult to detect contours of the bones which overlap each other.

In this paper, we propose a new method that dose not be based on TW2 nor use edge detection of bones but uses prototype based image comparison of hand bones, which realizes human-like evaluation of bone age.

# 2 Outline of the system

## 2.1 Extraction of ROI image

As this is the first step, among 20 bones of the hand, two typical bones, "the radius" and "the third proximal phalanx" have been chosen as regions of interests (ROI) in the present approach. Although the radius is the biggest bone among the bones of the hand, it is one of the most difficult targets in the sense of contour detection mostly because the gray levels of the boundaries and their neighborhood are nonuniform especially between the both sides of the bone. Therefore, the radius is a good target to show the efficiency of the proposed approach. In contrast to the radius, the proximal phalanx is one of the easiest target to analyze because of its clear image and good separation from other bones, hence it has been widely used in the automatic estimation of bone age. In these bones, the ROI image is extracted by a fixed size rectangle window which paid attention to the area "epiphysis" and "metaphysis".

## 2.2 Pre-processing

Firstly, as the pre-processing, the extracted ROI images compress to 1/64 in order to shorten the calculation time. Then, an algorithm of histogram equalization is employed to moderate the effect, and a thresholding operation which transforms a pixel value below the threshold which get from the gray level histogram to zero (back pixel) is performed to ignore the background noise outside the bones. Furthermore, median filtering on these images for smoothing.

## 2.3 Estimation of bone age

In the present approach, the bone age of an input image is determined according to the similarity with the reference patterns of which the bone ages are already known. Roughly speaking, the bone age assigned to the reference pattern which is closest to the input image is used as the estimated age.

As a decision rule and similarity measure, we employed the weighted average rule with the following similarity. The vectors consist of pixel values of the input image and reference pattern pattern respectively.

As for the reference patterns, we decided to use all of the ROI images obtained from the whole training dataset this purpose. We expect that the clustering technique could be useful for this purpose if much more training samples were available than now.

# 3 Experiments

An image database consisting of 19 girl subjects who were assumed to be normal was constructed for the experiment. In the database, each subject has an average of 8 radiographic images with the chronological ages from 5 to 20, and there are 154 image samples altogether.

In case of splitting the database into training and test sets, data from one subject were used for evaluation and data from the other 18 subjects were used for training. Hence, 19 possible combinations of tests were conducted in all.

The experiments are estimation of bone age using single bone, and 2 bones(radius and proximal phalanx). The estimated ages from the radius and proximal phalanx have been defined as a linear combination of the two ages.

# 4 Examination of practical

We experimented that estimation TW2 maturity stage instead of bone age, for assessment of pertinence of this present method.

For the purpose of practical, it is necessary the function to reject the input data which is difficult to estimation. Hence, we proposed the method that rejects the data which was determined as difficult to estimation.

To cope the individual difference of size of bone, it is necessary to normalize the size of bone. Then we normalized the size of bone by width of radius, or length of proximal phalanx.

The vector of the pattern, it is consisted of the pixels of ROI image. Then, we investigated about the quantization of the image.

# 5 Results

The estimation from single bone, it could be found that better performance is obtained around the age from 9 to 13 years old where a lot of samples are available comparing to the one for the marginal ages where fewer samples are supplied. Hence, in the present method, it is necessary to estimate that a lot of samples at the bone age, respectively.

The result of the estimation by 2 bones, it was better than by single bone. Therefore, we found that using several bones for estimation can improve the estimate precision.

From the result of estimation TW2 stage instead of bone age, it could be found that the estimate precision is nearly specialist does.

After the normalization size of bone, the estimate precision got worse. It was caused by the extraction precision of width of radius and length of proximal phalanx. Hence, it is necessary to improve the extraction precision.

At the images were more than 4-bit, there were no influence on estimate precision particularly. Hence, in the present method, images which are used for estimation of bone age, are needed more than 4-bit.