Computerized bone age estimation

Introduction

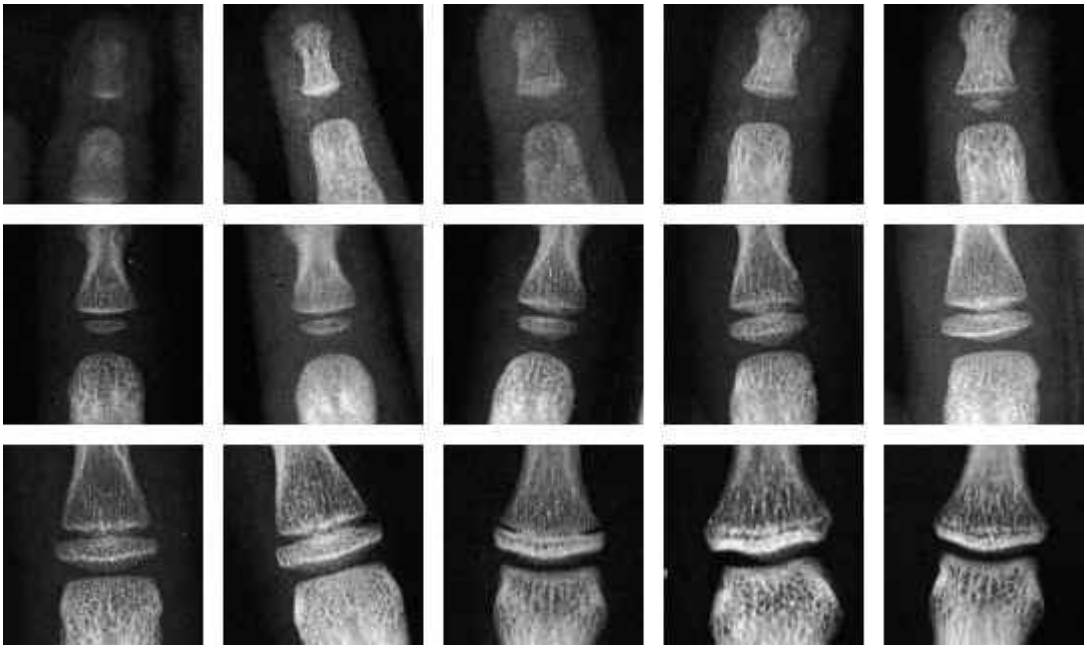
From the moment you are born until the time you're grown up, your bones go through a set a characteristic changes. Therefore the *skeletal maturity*, or *bone age*, can be estimated from radiographs of specific bones in the human body. Children who grow exceptionally slow or fast are often examined by making a radiograph of their left hand and wrist. Such a radiograph is shown below.

Hand radiograph of a 9 years old girl. The bone age is 8 years.

From this radiograph, the bone age can be estimated. From this estimate, together with other pieces of information such as the calendar age, sex and height of the child and possibly information about the parents, the adult height can be predicted. A big discrepancy between the calendar age and the

bone age can indicate an atypical skeletal development. In many cases the decision whether to treat a child with growth hormones depends on the outcome of a bone age estimation.

In the Wilhelmina Children's Hospital (University Medical Center Utrecht) around 700 of these examinations are made each year. It takes a radiologist several minutes to determine the bone age from a hand radiograph. The image is compared with reference photographs in an atlas. In this way the skeletal maturity of several bones is determined. Each bone develops in a characteristic way. This is illustrated for one bone in the image sequence shown below.

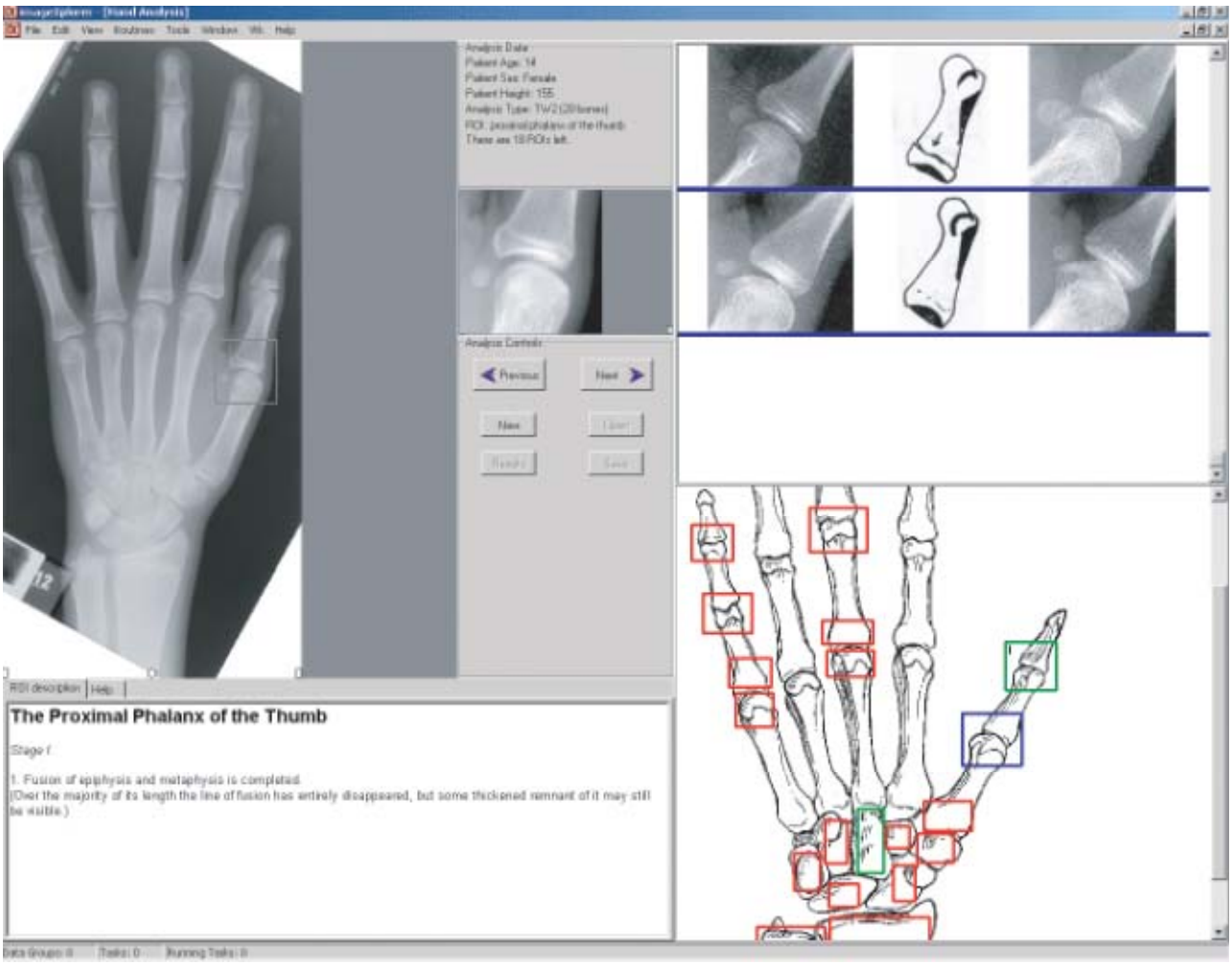


Development of the ring finger, row by row. The image top-left is from a baby, the image at the lower-right is from a nineteen year old. In the fifth image, the epiphysis appears, which becomes wider and in the final images fuses with the metaphysis. These images are taken from the Greulich and Pyle atlas.

In the Image Sciences Institute, we have started a research project to automate bone age estimation. A computerized bone age estimation would have the obvious advantage of saving radiologist's time. Furthermore, computer estimates are likely to be more reproducible than human estimates. Eventually, a computer analysis might also lead to more accurate predictions of adult height.

Software

As a first step, we developed a software program that can be used to perform the procedure of bone age estimation completely from a computer screen. The software is based on the method of Tanner and Whitehouse (known as the TW2 method). In this method, a number of bones must be identified and assigned to one of several (between 6 and 9) stages. The program was written as a plug-in for imageXplorer, the software development platform of the Image Sciences Institute.



A screenshot of the program for bone age estimation.

Automating the procedure

Basically the bone age estimation procedure consists of three steps:

1. Locating a region in the image with the bone of interest.
2. Assigning the bone to the appropriate stage.
3. After repeating steps 1 and 2 for all the bones of interest, the bone age can be computed from a table.

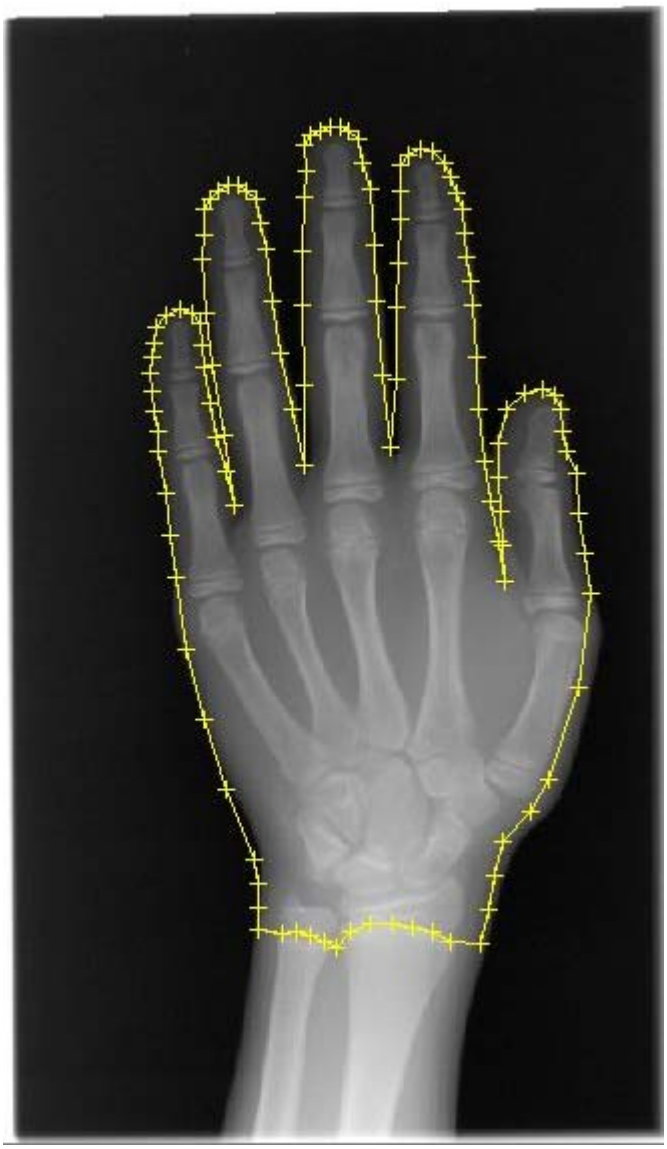
Automating the last step is trivial. Our research focuses on the first two steps.

Finding a bone

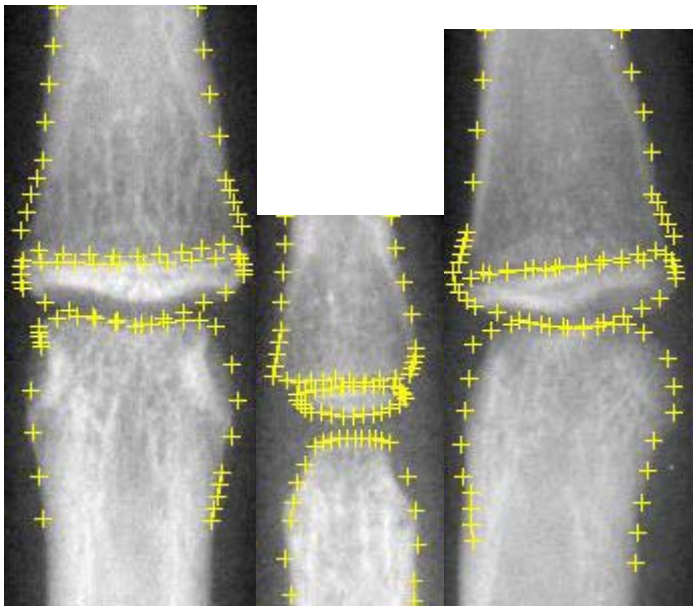
To locate the regions of interest, we are currently using Active Shape Models. First a model of the

outline of the hand is fitted to the radiograph.

The following animation shows the segmentation of the outline of the hand.



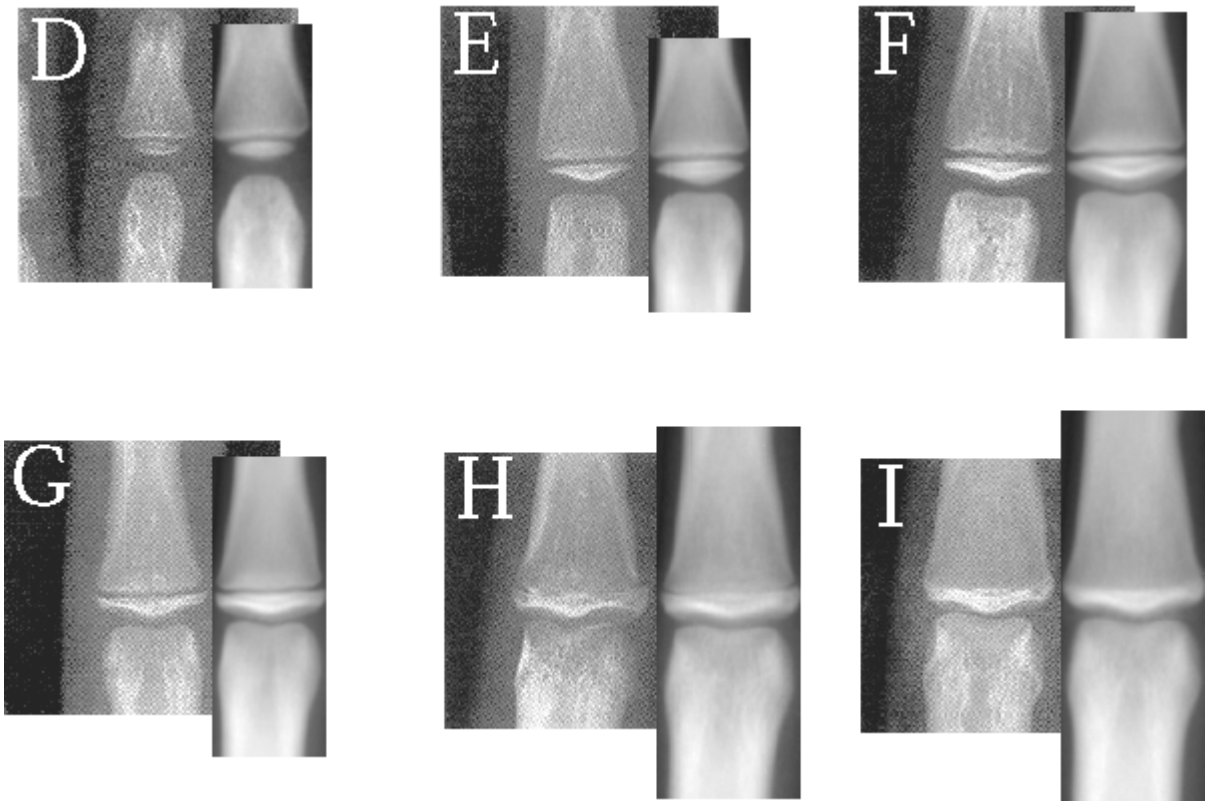
Based on the outline, a good initial estimate of the region of interest for each bone can be determined. Using this estimate, another Active Shape Model then finds the bone. Below are three results.



Result of segmenting the meta- dia- and epiphysis with an Active Shape Model. Note that the results are quite good although there is a large variety in the stages of the bones and only a single Active Shape Model, trained with examples from all stages, is used.

Staging a bone

In order to stage a bone, we construct for each bone a model of each stage. A simple model would be the mean image of a stage, after registration of a number of training images of a single stage. The TW2 method is also based on comparing a bone with typical instances of each stage. The mean images of a stage show a remarkable similarity to the typical instances of the TW2 method.



In the square images, typical instances for several stages of the middle phalanx of the third finger from the TW2 method are shown. The insets are mean images produced from our training data.

To assign a stage to a new image, the region of interest is segmented by Active Shape Models, and the bone is registered by translation and scaling to the mean image of each stage. Correlation can be used to determine the best stage. We are currently also investigating more complex methods that use multiple features.

Results

We performed an experiment on data provided by the University Hospital of the Catholic University of Leuven, Belgium. The mean images and Active Shape Models were trained from 134 images. The stage of the middle phalanx of the third finger was determined by the computer. The method obtained a correct score of 73%. in only two cases the computer was off by more than one stage. In comparison, a second manual rating gave 80% correct and had never more than one stage difference.

References

This page describes work by Bram van Ginneken, Meindert Niemeijer, Casper Maas, and Jurjen de Vries.

[1] "Assessing the Skeletal Age From a Hand Radiograph: Automating the Tanner-Whitehouse Method", M. Niemeijer, B. van Ginneken, C. Maas, F.J.A. Beek, M.A. Viergever, in: *Medical Imaging 2003: Image Processing*, Editor(s): M. Sonka, J.M. Fitzpatrick, SPIE, 2003.
