Skeletal Maturity Assessment Client-Server Application

Sorana Daniela BOLBOACÃ

Lorentz JÄNTSCHI

Carmencita DENEŞ

Andrei ACHIMAŞ CADARIU

Sorana Daniela BOLBOACÃ. Andrei ACHIMAŞ CADARIU

Medical Informatics and Biostatistics Department

"Iuliu Haţieganu" University of Medicine and Pharmacy

Emil Isac 13, 400023 Cluj-Napoca, Romania

e-mail: sbolboaca@umfcluj.ro

Phone: +4-0264-431697

Fax: +4-0264-593847

Lorentz JÄNTSCHI

Science and Engineering of Materials Faculty

Technical University of Cluj-Napoca, Romania

Carmencita DENEŞ

Radiology Department

"Axente Iancu" Paediatric Clinic No. 1 Cluj-Napoca, Romania

Abstract

An original client-server application for paediatric radiologist's use, that is executable on a stand-alone computer, or using a server when it acts as a real client-server application was developed. In order to create the application the Tanner-Whitehouse method was used. The application had two essential parts: a part for bone age assessment, which is the client side for the application and a database part for physicians, patients and consultations management, which is server side of the application. The implementation was performed using HTML and JavaScript for the client side and PHP&MySQL for the server side. The application integrates the Tanner-Whitehouse method in a stable and reliable environment. The application allows inserting and selecting patients, the performing of TW2 tests, and to inserting and selecting consultations. The minimum requirement for the application execution is an Internet browser. In order to store and retrieve patients and consultations the requirements are a MySQL database server and an Apache web server. Our application improves radiologist's efficiency, allowing the decreasing of the computational errors and the assessment time for bone age. The database component of the application proves to be very useful in creating of an integrated system for patients and consultation management.

Web page: http://vl.academicdirect.ro/medical_informatics/bone_age/

Key words: Age Determination by Skeleton · Diagnosis, Computer-Assisted · Client-Server Application

Introduction

The quick development of the Internet in the last years leads to a similar increase of all services accessible over the web in all day-to-day activities domains. Nowadays, we can also talk about evidence-based medicine web sites, which provide a large amount of medical knowledge, most of them being organized in medical databases [1]. Client-server applications facilitate the use of large databases of clinical information, which can be softly accessed at

different computers without creating parallel evidences and requires the minimum specific software to be installed.

In paediatrics, the skeletal maturity is an important quantitative measure for the clinical diagnosis of endocrinological problems and growth disorders and it can be assessed by analysing of the ossification centres of the hand, foot, knee, elbow or pelvis, although the most frequently used are the hand and the wrist radiography. Usually, the bone age evaluation is achieved by assessing the ossification and maturation of the epiphysis of the hands and wrists as compared to the standard radiographs and standard descriptions. There are at least two methods of evaluating wrist and hand bone age, represented by the Tanner-Whitehouse (called also TW2) [2] method and the Greulich-Pyle method [3]. Note that the Greulich-Pyle and the TW2 method do not give equivalent bone ages [4, 5].

The TW2 method implies the examination of 20 hand and wrist bones and the description of each bone's stage according to the clearly described bone-specific maturity indicators. According to the TW2 tables, every bone stage is given a numerical score, and the scores are summed up resulting a maturity score for each individual on a scale of 0 to 1000. Using the TW2 tables, maturity scores are converted to bone age for each individual and the relative maturation can be assessed by comparing the bone age to the individual's chronological age. A disadvantage of the TW2 method is that it takes a lot of time to estimate a child's bone age, using the classical way (between 8 and 10 minutes for each patient).

The aim of this research was to develop a useful client-server application that is to serve to computing TW2 test in order to decrease the assessment time and to manage all the activities related to skeletal maturity assessment.

Methods

The computerized assessment can be divided in two parts: one for the bone age assessment and one for the information management. Our application obeys to this division.

The visible part of the application consists of the client interface, which mainly reefers to bone age assessment. Behind this interface are HTML (Hyper Text Markup Language) and JS (Java Script). On an Internet browser, the application displays a web page with a set of standard radiological images and associated descriptions to make possible to assign a maturity stage for each bone from a real radiological image. For of every the 20 possible bones, the physician must choose a maturity stage from 7 or 8 possible stages using a radio button group. If a MySQL database server is available, at the end of evaluation the task, the physician can save the information (examination date, bone age, maturity bones stages, maturity score and diagnosis) in a MySQL database called `TW2`. The database contains five tables called `Patients`, `Consultations`, `Physicians`, `Bones`, and `BoneStages`. The tables `Patients` and `Physicians` are primary tables, and the `Consultations` table has the filed `PersonalNo` as foreign key from `Patients`, and `Physician` as foreign key from `Physicians` (Fig. 1). The application also uses two other tables, `Bones` (primary table) and `BoneStages` (with `bone` foreign key from `Bones`) used for client interface (Fig. 1).

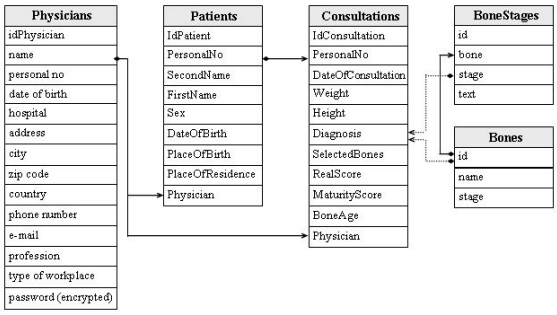

Figure 1. Database structure and connectivity

The server part of the application is responsible for information management and it requires a MySQL database server and an Apache web server with PHP interpreting modules included. Our system (vl.academicdirect.ro) is an UNIX-like system (FreeBSD, 5.2 current version) with Apache (2.0 version), MySQL (5.0) and PHP (5.0) installed.

With access to an Internet connection, using the program is made easily (Fig. 2).

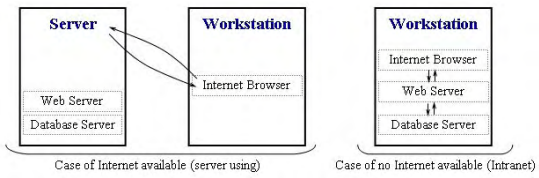

Figure 2. The environment of the application and client-server communication

All that we have to do is to put the URL (Uniform Resource Locators) of our program in the browser:

http://vl.academicdirect.ro/medical_informatics/bone_age/

The vl.academicdirect.ro server will send the client interface page to the client computer and the assessment procedure can begin. Note that our database system is secured, so in order to use it as a physician (to have the rights to select and insert patients and consultations) you must register first.

In order to run the application on a stand-alone computer a good idea is to use as server package the PHPTriad program [6] which contains all required environments (web and database server). Note that in this case, the user of the program must recreate the database structure. More, if you do not want to store the patient and consultation information into a database, all that you have to do is to save the program web page on a local hard-drive (Fig. 2). Anyway, the Fig. 2 represents the needed environment of the application.

The server part of the application uses the PHP language to perform the tasks we need. Our application has 10 PHP programs: stiluri.php, password.php, index.php, info.php, info_n.php, info_cons.php, patient.php, NewPatient.php, SaveConsultation.php, and tw2.php, all located into the bone_age directory.

Two of these programs, represented by the stiluri.php and password.php, were used in all our programs. Stiluri.php is an additional file in which we defined some GUI styles (graphical user interface) that are used in the client side. This allows us to reduce the number of ″rows″ in programming. The connection to the TW2 database was made through the password.php program. Inserting new patient information into the database is made possible by using patient.php program. The new patient registration is achieved by using a SQL phrase:

INSERT INTO `Patients` VALUES ('','<value>',…, '<value>')

Where the first value is an empty one and represents `IdPatient`, which is a numeric field, primary key being incremented automatically by MySQL database server. If the patient has been already registered, no other registration is allowed for the same `PersonalNo` filed. Patient selection is also made through a SQL phrase:

SELECT `PersonalNo` FROM `Patients` WHERE `PersonalNo` LIKE

'$_POST['PersonalNo']'

where $_POST is an array which contain all submitted information. The tw2.php program sends the interface to the client for the TW2 test. The interface implementation is made by using of JS language because it is a simple and easy environment already integrated into HTML documents. On the other hand, Java Script programming language allows interactivity with the users and can be especially proceed to create online mathematical algorithms. Using the info.php program, one can interrogate the database to find information about patients and consultations. We can interrogate the database for information about the patient if we choose the Consultations option from Option drop down list, or to get a report if choose the Report option. The Consultations option allows us to create an individual patient report. The Report option allows creating a report with all the patients' data from the TW2 database.

Results

A lot of information is generated by the application. Starting with patient inserting and selecting (Fig. 3), continuing with performing of TW2 test (Fig. 4) and ending with printing of consultation report (Fig. 5) the application integrates all the tasks required in an ordinary consultation. More, if the patient already exists, we can generate a report with his consultations history. The consultation reports can be printed or saved in order to send the consultation results to the specialist or the family doctor.

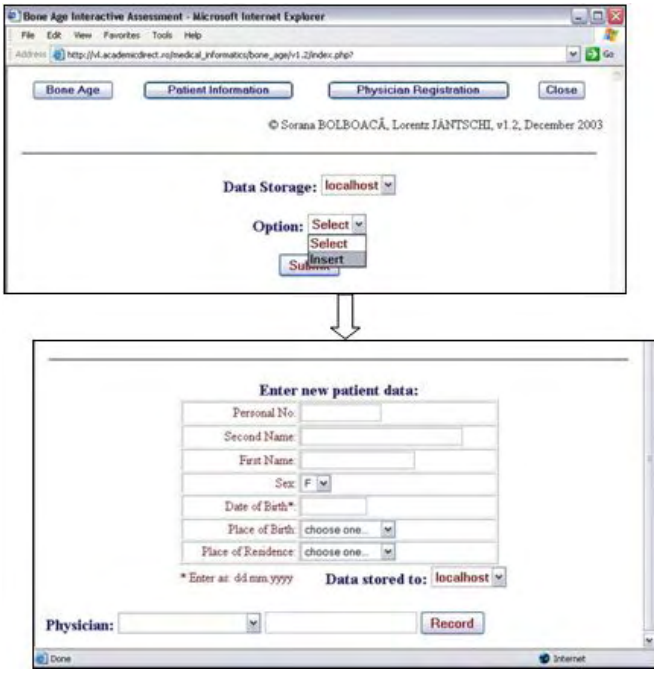

Figure 3. The insert patient information interface (client side image)

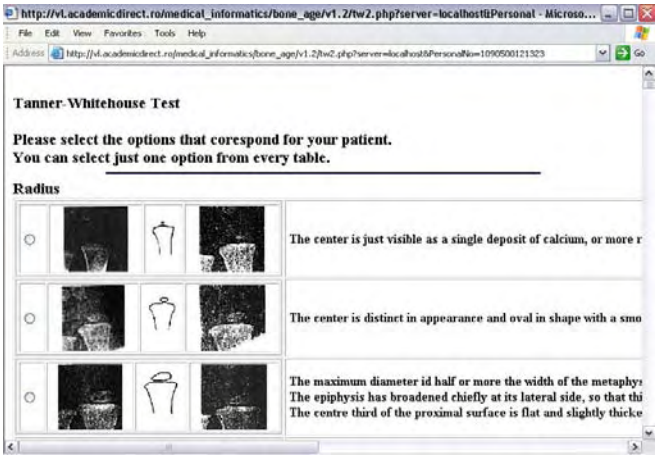

Figure 4. The maturity score assessment interface

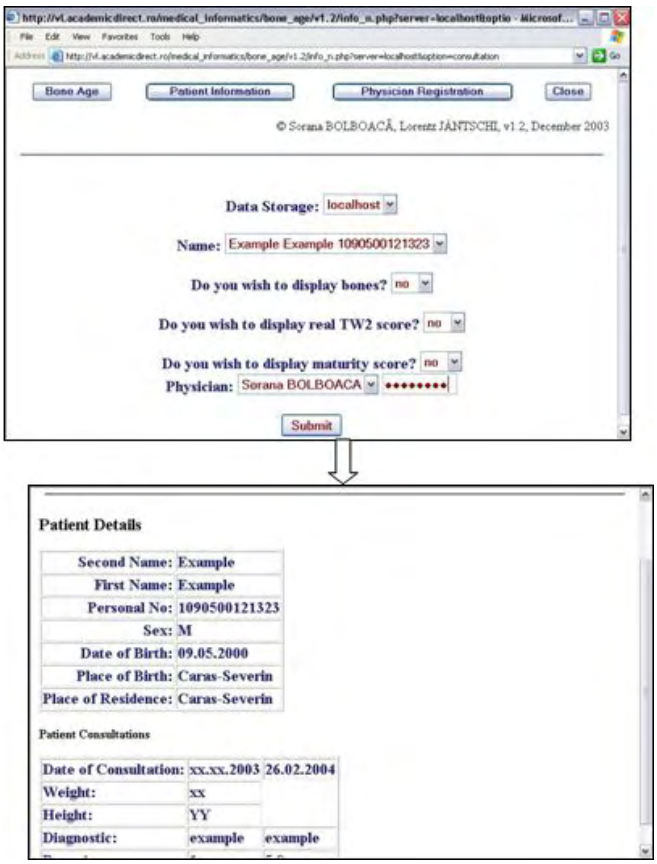

Figure 5. The consultation report interface

In order to respect the patient confidentiality and protect the patient's data, the input of patient information, the computing of the bone age and the creation of any individual report are password protected and may be accessed only by registered physicians. The one who is interested in the program using has to fill a registration form available on site and send the information to the administrator. The database administrator will assign a password and send it back to the person who requested the registration.

Discussions

There are many computer programs all over the world, most of them using the pattern recognition [7] with algorithms based on the Tanner-Whitehouse methods [8,[9]] or using some algorithms based on carpal bones score [10]. All these programs are running in those countries where the radiological devices are able to store digital images, as the pattern

recognition is supposed to work with high quality right-hand radiographs in order to compare correctly the particular image with the standard one.

Our project aims to meet the more specific needs of paediatric radiologists who work with less sophisticated radiological devices and to help them in easily assessing the child's bone age. The aim of the project was to allow the paediatric radiologists to introduce some general data of the patient into a database, to assess the child's bone age assisted by the computer and to perform interrogations on the database in order to obtain reports containing the actual and previous consultations. The application is an integrated system of medical information used in child bone age assessment easy to integrate and to use into a hospital environment. All physicians that use the program had a user name and an encrypted password, which allows protection of medical data stored in the databases.

We can say that the application has some advantages:

- The needed time to obtain the final bone age is significantly reduced to 3-5 minutes as compared to 8-10 minutes needed by any radiologist when doing a paper evaluation;
- Using this program, the radiologist avoids making computational errors (in both score and bone age) which often occur when using paper as a support for evaluation;
- All the data is being saved in a database and can be interrogated any time for retrieving previous consultation data and for research performing.

The accuracy of the computerized procedure depends on the radiologist's ability to use a web browser. On the other hand, it also depends on the radiologist's experience, which is essential. The application can be also used by residents in radiology undergoing the paediatric radiology-training module and, of course, by the paediatric radiologists in their everyday work. The program was tested by a paediatric radiologist from Cluj-Napoca.

The program may be extended in order to compute RUS bone maturity score – this score using the radius, ulna and finger bones, and/or Carpal bone maturity score – using only carpal bones. An automated system of bone age maturity evaluation applied on the base of the

Tanner-Whitehouse method may also be created, but this will be possible only when the paediatric hospitals will be equipped with proper radiological devices.

Conclusion

Based on the Tanner-Whitehouse method, we have developed computer-assisted software for bone age assessment of children and young people using PHP, MySQL and JavaScript. The application is a useful integrated system for children skeletal maturity assessment management. The patient confidentiality and the data security are maintained using encrypted radiologists accessing passwords. The program significantly reduces the time needed to obtain the final bone age and eliminates some of the computational errors in both score and bone age, error that often occurs when radiologists use paper as a support for evaluation; it also allows storing patients information as well as patient consultations data.

The program interface, which was dynamically created in JavaScript in order to facilitate a faster access, allows interaction with the users and can run on any computer. This is a program quite easy to install in any clinical environment, proving to be a powerful tool for day-by-day application in paediatric radiology.

References

[1] Delvenne Catherine, Pasleau F. Organising access to Evidence-Based Medicine resources on the Web. ELSVIER. 2003;71:1-10.

[2] Tanner J. et all. Assessment of Skeletal Maturity and Prediction of the Adult Height (TW2 Method). Academic Press. London/New York.1983.

[3] Greulich WW, Pyle SI. Radiographic atlas of skeletal development of the hand-wrist. Stanford University Press. California.1959.

[4] Bull RK, Edwards PD, Kemp PM, Fly S, Hughes IA. Bone age assessment: a large scale comparison of the Greulich and Pyle, and Tanner and Whitehouse (TW2) methods. Achieves of Disease in Childhood. 1999;81:172-173.

[5] Milner GR, Levick RK, Kay R. Assessment of bone age: a comparison of the Greulich and Plye, and Tanner and Whitehouse methods. Clin. Radiol.1986;37:119-212.

[6] SourceForge.net [homepage on the Internet]. PHPTriad [cited 28 September 2003] Available from: http://sourceforge.net/projects/phptriad

[7] Meindert Niemeijer, Casper Maas, Bram van Ginneken. Automanic skeletal age assessment [cited 2003 June 3] Available from: http://www.isi.uu.nl/People/Meindert/

[8] Dickhaus H, Habich R, Wastl W, Schőnberg D. A computer based system for skeletal maturity assessment. Medical signal and image processing. 20th Annual Conference of the International Society for Clinical Biostatistics. 1999 September. Proceedings. 1999;13:11-20.

[9] Cabello AS, Esrtada RC. Sistema Automatizo de evaluación de la maduratción ósea aplicado al método Tanner-Whitehouse 2. Anales Espanoles de Pediatria.1999;50:134-139.

[10] Bo-Chun Fan, Chi-Wen Hsieh, Tai-Lang Jong, Chui-Mei Tiu. Automatic Bone Age Estimation Based on Carpal-bone Inage – A Preliminary Report. Chin Med J.2001;64:203-208.