



*medical imaging informatics,
on-line atlas,
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EDUCATIONAL ON-LINE ATLAS OF IMAGES OF RESPIRATORY SYSTEM

An educational on-line atlas of images of respiratory system is described in this paper. It is a teaching and testing tool designed for faculty and students to exchange experiences and to collect and review interesting cases useful in diagnosis making process and teaching. A dedicated atlas database is able to store study description data, compressed image data and high resolution DICOM files as well as multimedia files of studies collected in clinics. Currently the database contains 85 studies of pathological and normal cases. Communication and of a user with the atlas application and the database is provided by graphical interface (GUI) accessible via web browser. Management of the database and user accounts can be also remotely performed via GUI. GUI has been approved by clinical expert as useful in clinical practice. Based on collected studies a testing unit built in the atlas offer various tests created by entitled users. Atlas application provides restricted access for anonymous and unregistered users.

1. INTRODUCTION

Dynamic development of the Internet and its usefulness in exchanging medical knowledge and image data draws attention of users, designers and developers. Various kinds of computer aided diagnosis software used in clinical practice and electronic atlases play an important role in medical diagnosis support and training process due to easy access, fast query of interesting cases and short time of atlas applications' response. The basic concepts of electronic atlases (EA) are dedicated to the exchange of medical knowledge, improvement of the diagnosis-making-process [1], as well as support in teaching faculty and students. Present medical atlases are available in the following forms: books, electronic atlases issued on transferable media (CDs, DVDs) and electronic repositories accessible through websites. Utilizing the last form ('latter' is used for 2 items) is usually registration based and free. Electronic resources with medical atlases are usually designed and created by academic communities and medical schools or hospitals. Examples of such vast repositories can be found in Harvard and Yale [2] websites.

Currently available EA are devoted to imaging and description of particular organs, systems or body parts. The limitation comes largely from the data collection process. A careful selection of cases is usually difficult, time consuming and requires an expert knowledge. Currently, a number of

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free access atlases containing normal and pathological images of respiratory systems (RS) is limited [2] or they refer only to the part of RS; for instance, [3] refers only to bronchoscopy. Although these EA contain image data with or without medical report, there is lack of teaching and testing tools provided on these websites. Additionally, images in the uncompressed (diagnostic, DICOM) format are not available to download even for registered users.

In this paper an educational on-line atlas of images of respiratory system is presented. It contains eighty-five cases that are split into parts of normal impression of lungs, as well as pathological cases of RS. Image data with associated medical records are stored in a relational database server. The atlas application also contains built-in teaching and testing tools. A graphical user interface (GUI) gives a user access to the data repository through queries' system via a web browser window. Registered users are entitled to download diagnostic images in the DICOM format, add new images to collected studies, add new studies, update the database and edit medical reports.

2. MATERIALS AND METHODS

The goals of the application are for it to be easy to use and fully accessible through the WEB. In order to collect and store image and text data, an appropriate database system was designed. It is based on a relational database model implemented in MySQL language [4]. Communication with the database is implemented by SQL queries nested in PHP (Hypertext Pre-processor) code [5]. The idea of the atlas is based on Three-Tier Application Architecture (fig.1) containing the following layers: data, application and presentation. The data layer and GUI are described in following sections. To reduce hardware and software user's requirements the 4th WWW (World Wide Web) web page generation was used in order to run database and application on the web-server. An IIS server (integrated with MS Windows operating system) was selected for this purpose [6]. The atlas application was designed in HTML and implemented with PHP programming languages installed on the WWW server.

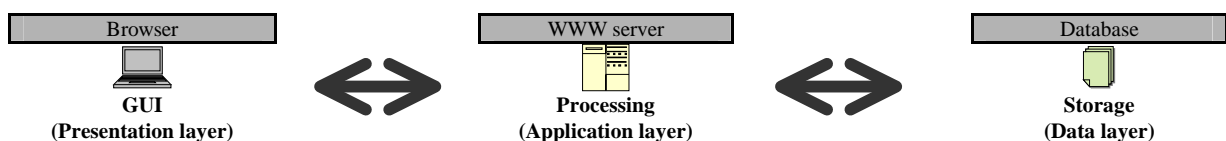


Fig.1 Three-Tier Application Architecture

The atlas of images of respiratory system (AIRiS) is run on the web-server, which communicates with the database. Queries of users from the GUI in the browser window are processed by the application and sent to the database. Communication between the GUI and application is carried out via TCP/IP and HTTP protocols [4].

2.1 DATABASE STRUCTRE

In the data layer three types of data are stored in the database system: image data (JPG, AVI, DICOM files) with medical records (text files), user data and tests. Hence, database has been

divided into three units (fig.2). User Unit contains one table with user text data. It encompasses user name, login name and password. Every user also has a status assigned to them during registration process. A status value reflects access and rights of a user to particular units and services in the database. User rights are explained in the section below.

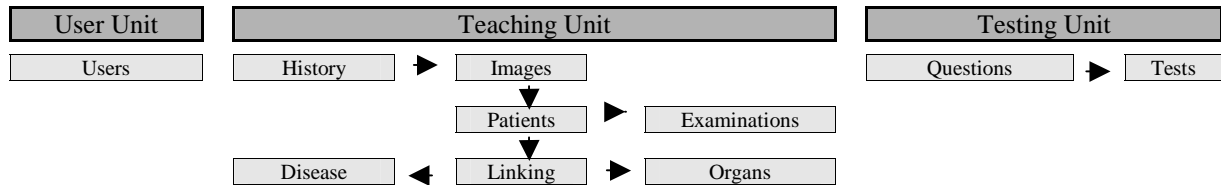


Fig.2 Database structure with units. Arrows mark links between modules of particular units.

Testing Unit consists of two tables with relations of table fields of type 'many to many' [7]. Each new test can be created by restricted users based on a set of questions that ought to be stored in the database before the test is created. Users of the same category may also input new questions and answers to the Testing Unit. A user also has the capability to generate tests based on random selection of certain types of questions. Teaching Unit is a more complicated type of table. Relations between table fields are reflected by a 'one to many' relation model. This unit is composed of 7 normalized tables. Each table contains a primary key that is indexed. There are also foreign keys in nested tables linking, patients, images and patients' history. Due to normalization procedure [8], it was necessary to create auxiliary patients' table and linking table connecting dictionary tables (disease, organs and examinations) to minimize redundancy in the table structure. To reduce storage space of database structures all images are stored in separate server folders. Image data is associated with fields in database by primary keys, so that name of each image is equal to a primary key of a certain study stored in the database [9]. One study may contain up to 15 images. This information is stored in the history table. A set of primary keys of images stored in the history table points to the image files of the certain study. When a new image is being added it is uploaded to the unique study folder, and the history table and set of primary keys are updated.

2.2. GRAPHICAL USER INTERFACE (GUI)

The GUI offers an access to the atlas through navigation panels in a web browser window. A main bar in the top of the GUI window (fig.3) contains links to the Teaching and Testing Units, help module and database update module.

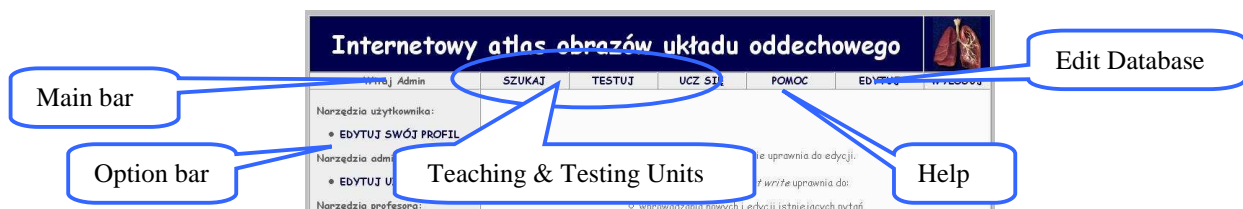


Fig.3 GUI. Teaching and Testing Units window.

The help module was created to provide instructions related to services and options built in the atlas application.

2.2.1 ACCESS TO TEACHING AND TESTING UNITS

The AIRiS provides technical information about modalities used in imaging of RS as well as any medical information about diseases of RS included in the Teaching Unit. The Teaching and Testing Units are linked to the database and HTML info files (fig.4). Content of database is available through the GUI. An example of a study from the database is shown in fig. 5 and fig. 6.

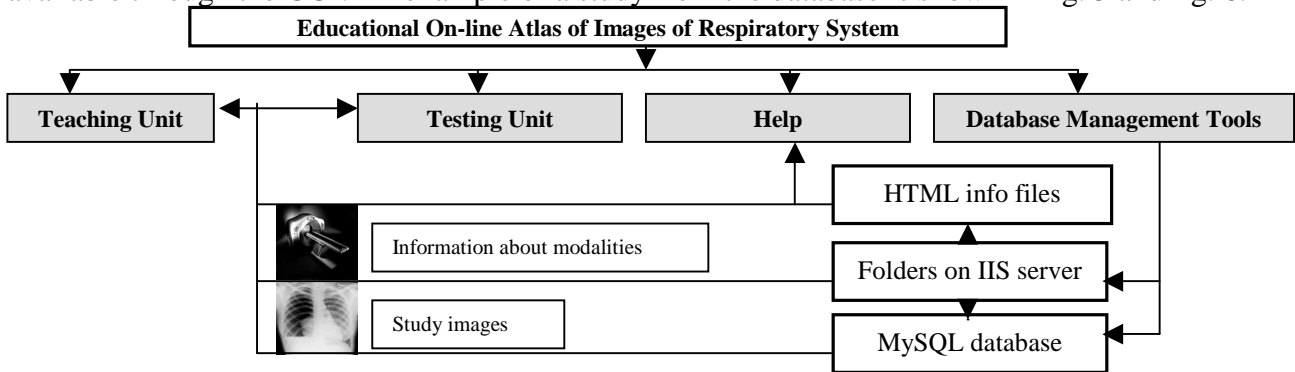


Fig.4 Teaching and Testing Units and their links to the database.

The interactive part of the Teaching Unit displays image data (and movies) with a description of pathology (fig.5). All studies collected in database are available from the Teaching Unit level. While new images are being stored, it is necessary to provide the date of examination and medical report data in order to complete a record entry. It is possible to store a single image for each study as well as series of images acquired at different times. Uploading a DICOM file is possible after obligatory patient data anonymization.

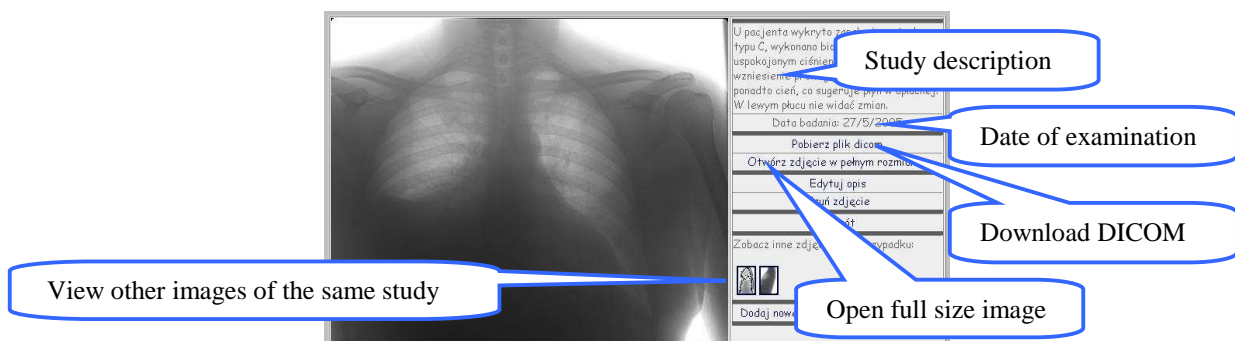


Fig.5 GUI. Teaching Unit – data presentation

The database can be searched by disease, examination type or a part of respiratory system. As a result, a list of icons is created and displayed in the GUI window. A user is able to view an image in either a fixed size in a GUI frame or in full size by opening it in a new browser window. An example of database record update is presented in fig. 6. There is also a possibility to edit the medical report of an existing study or append a new image to an existing study. Appropriate tools are available through the GUI (fig.6) for that purpose. The user may also add a new case via a link from the main bar (fig.3).

The Testing Unit is an augmentation of Teaching Unit. It contains two variants of tests: random tests pertaining to a chosen domain or predetermined tests already stored in the database. While solving tests, a user has to mark answers which are sent back to the Testing Unit for checking. A score with the quantity of correct and wrong answers is provided to the user immediately. Moreover, Testing Unit generates a list of all correct answers and sends it back to the GUI. [10].

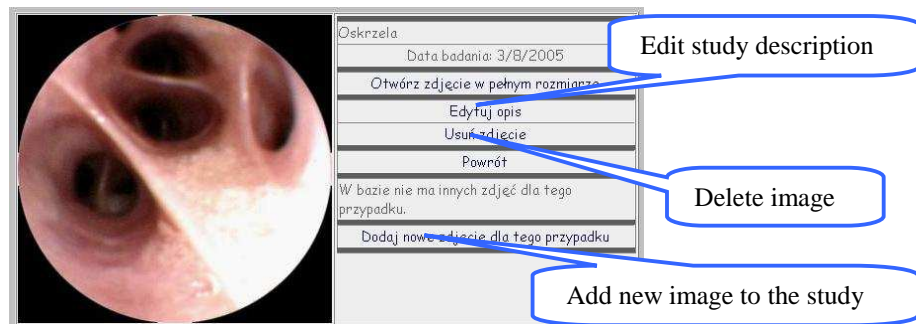


Fig.6 GUI - Image Unit. An example of the record update

2.3 USERS

In order to provide access at various levels, five types of user account were created: *root*, *read and write all*, *read and write test*, *read only* and *anonymous*. Anonymous users may use the service without login and password, but they will have limited access to collected data. They may browse images with medical reports and without full access to teaching and testing tools. Full access to Teaching and Testing units is restricted to registered users only. All users with *read and write test* rights can modify Testing Unit. Changes in Teaching Unit can be made by users with *read and write all* status. Full access to the whole service with rights to manage all users is available only for *root* user. Every registered user may change his password via GUI at any time. Name and status of currently logged-in user is stored in session data. Number of users logged-in at the same time is not limited. [10].

2.4. IMAGE DATA

Currently, AIRiS database contains 85 examinations (Table 1). All studies with medical reports were collected at the Clinic of Lung's Diseases and Tuberculosis in Zabrze and Centre of Diagnosis and Laser Therapy in Bytom. Before the image data had been included in the database, all cases were consulted and reviewed by a lung disease expert. Next each image file and medical report was subjected to an anonymization routine. The current collection of studies with affirmed pathologies has been split into 14 groups reflecting various lung diseases. There are also 9 cases of respiratory system with normal appearance. All single images are stored in JPG format. Additionally some of the images are also stored in DICOM format. One movie file has also been uploaded.

Table 1 Database content

Examination type	Number of examinations	Image Data type		
		JPG	AVI	DICOM
Bronchoscopy	21	21	1	
Bronchography	1	1		
Computer tomography	17	17		
Videotoracoscope	6	6		
X-ray	40	40		16
Total number	85	85	1	16

2.5. SYSTEM IMPLEMENTATION

The AIRiS application is currently installed and available for registered and anonymous users at the Silesian Technical University's server with URL <http://157.158.17.138/pluca>. The Clinic of Lung's Diseases and Tuberculosis in Zabrze is a database owner and is in charge of database administration, providing access for users and database management. At present, AIRiS is available only for registered users as well as *anonymous* and for only educational and testing purposes. A user is able to run the application using a web browser. Since AIRiS database may include movie data, a user should have installed plugged-in tools for display of video files.

4. RESULTS AND CONCLUSION

The on-line Atlas of Images of Respiratory System has been designed, implemented and successfully installed. Currently it consists of 85 different cases grouped in disease related categories. The application has built-in tools useful in the study of respiratory system diseases and functions. The service also provides information on how certain modalities can be used in diagnostics of respiratory system. The on-line service is dedicated mainly for physicians and students. It provides the possibility to systematize interesting pathological cases met in practice by physicians and may be useful in teaching. The service allows adding new data records and saving disease history with subsequent updates of any part of the record. The capability of storing DICOM images that could be downloaded from the database makes the service more useful comparing to the existing solutions. The GUI has been approved by a clinical expert as useful in clinical practice. In future works, AIRiS is being considered to be translated into an English version.

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