Imagistic Digital Library for Hybrid Medical Learning

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Abstract. The paper presents an e-learning platform (TESYS) that enhances the possibilities of the traditional medical teaching. It allows students to use modern tools for information access and continuously testing their knowledge. Although medical learning cannot replace direct transfer of knowledge performed during hospital practice hours, when the teacher presents to students different medical cases with all complementary information (medical investigations, diagnosis, applied treatment, disease evolution), the e-learning solution can offer significant advantages It can be said that the hybrid learning is the best solution for the medical teaching. An element of originality brought by the TESYS platform is a medical imagistic database that can be updated by the specialists with images acquired from different patients in the diagnosis and treatment process. A series of alphanumerical information: diagnosis, treatment and patient evolution can be added for each image. The second element of originality is the content-based visual query that uses characteristics that were automatically extracted from medical images (color, texture, regions). It can be used both in the training process and e-testing process. Using content-based visual query with other access methods (text-based, hierarchical methods) on a teaching image database allows students to see images and associated information from database in a simple and direct manner. This method stimulates learning, by comparing similar cases along with their particularities, or by comparing cases that are visually similar, but with different diagnoses.

Keywords: hybrid medical learning, imagistic medical database, content-based visual query, color feature, texture feature, color region

1 Introduction

The hybrid or blended learning describes the learning method in which some traditional face-to-face “seat time” has been replaced by online learning activities. The purpose is to take advantages of both face-to-face and online learning [11], [12].

Although medical learning cannot replace direct transfer of knowledge performed during hospital practice hours, when the teacher presents to students different medical cases with all complementary information (medical investigations, diagnosis, applied treatment, disease evolution), the e-learning solution can offer significant advantages which were highlighted in medical literature: increased accessibility to information, better updating solutions, personalized training, better distribution, standardization of content, better efficiency in achieving knowledge and aptitudes [4], [5], [7], [8], [9].

Due to all these advantages medical e-learning has become more and more important and more frequently used in the last decade [1], [2], [3], [6], [7]. The technological development and the Internet contributed to the development of e-learning resources. Repositories and digital libraries for access to e-learning materials were established (MedEdPortal, Association of American Medical Colleges, End of Life/Palliative Resource Center, The Health Education Assets Library, Multimedia Educational Resource for Learning and Online Teaching, International Virtual Medical School) [10].

The accomplished studies, including those focusing on medical domain, indicated that the students substantially appreciate the e-learning method, due to the facilities offered (easy access to materials, navigation, interactivity, friendly interfaces), but they don’t consider it as a replacement of the traditional learning which has other advantages [8].

The introduction of the multimedia components (text, images, sound, video, graphics, animation) for the improvement of the learning content led to the necessity of the concept which precedes even the Internet, i.e. the multimedia learning. Both teachers and students consider that the multimedia learning improves the process of teaching and learning [10].

There is an increasing need to assess aspects of professional behavior and competence within the health system. The right evaluation of the students in the medical area represents an important problem and should be done in a complex manner, guaranteeing that the students will become competent and professional doctors. That is why the testing should be more complex than multiple-choice tests of knowledge and multi-station tests of “presupposed” clinical skills using simulated patients.

The paper presents an e-learning platform (TESYS) that enhances the traditional medical learning methods, allowing students to access modern methods to transmit information and test their knowledge.

Besides traditional functions, an element of originality brought by the TESYS platform in the hybrid medical teaching is a color digital images library, structured as a database updated by the specialists with images acquired in the diagnosis and treatment process, from different patients. Each image can include a series of alphanumerical information: diagnosis, treatment and patient evolution. It means that along with the electronic teaching documentation for the classic teaching methods, there will be a database with medical images.

In the medical learning process, the courses in traditional or electronic format, are accompanied in many cases by a series of images. For example, at a gastroenterology course, for the presentation of the ulcer diagnosis, the teacher presents to the students images that are relevant for this diagnosis, highlighting the changes in color, texture or shape of the sick tissue, in comparison to a health one.

In general, the presented images number is minimal. Accordingly, the existence of a database with medical images (of order of hundreds) that could be collected by the teacher in the process of patients' diagnosis and investigation raises considerable the variety of communicated knowledge.

This digital library with images can be used both in the learning and testing process. It uses a modern query method, namely content-based visual query. Medical learning is the most important direction for using content-based visual query, besides diagnostic aid and medical research, as presented in the specialty literature [15].

The students can use the medical imagistic database in the training process. They can query the database in two different ways:

- Traditionally, by the text-based method; for example, the diagnostic is written and all the images associated to it are searched in the database.

- Content-based query; in this case keywords or other texts are not used. The query uses the characteristics extracted from images (for example color or texture). This type of query is implemented taking into account the whole image, or only parts of it (regions). In the first case the name of the query is content-based image query. It will find in the database all the images that are significantly similar to the query image. In the second case, the name of the query is content-based region query. It needs to be selected one or several regions used as query regions and it searches in the database all the images that contain the selected regions. In this case it is necessary to have an automated region extraction algorithm for images, using certain characteristics (for example color) [13], [17].

To use the imagistic collection and content-based visual query in the testing process, the TESYS platform offers a solution that can replace or complete a usual mode for knowledge testing: the teacher presents to the student the image of a patient and he/she has to study it, establish a diagnosis and make observations. More than this, the electronic solution challenges the student to recognize similar images that are included in the same diagnosis class, or visually similar images, but of different diagnosis. Such complex testing allows the teacher to evaluate student's knowledge more efficiently and deeply so that he can take the right decisions. The role of proficient testing methods is very important in the medical domain, where establishing a wrong diagnosis based on the imagistic investigations can have serious consequences on a patient.

Using content-based visual query with other access methods to medical imagistic database allows students to see images and associated information in a simple and direct manner. They only have to select a query image and find similar ones. This method stimulates learning, by comparing similar cases or by comparing cases that are visually similar, but with different diagnoses [15].

2 Medical e-learning Platform Description

The main goal of the application is to give students the possibility to download course materials, take tests or sustain final examinations and communicate with all parties involved. To accomplish this, four different roles were defined for the platform: sysadmin, secretary, professor and student.

2.1 Roles

The main task of sysadmin users is to manage secretaries. A sysadmin user may add or delete secretaries, or change their password. He may also view the actions performed by all other users of the platform. All actions performed by users are logged. This way the sysadmin may check the activity that takes place on the application. The logging facility has some benefits: an audit may be performed for the application with the logs as witness; security breaches may also be discovered.

A sysadmin user may block an IP so that no user will be able to access the application from that IP. Finally, the overall activity of users represents valuable data. This data may be off-line analyzed using machine learning or even data mining techniques so that important conclusions may be obtained regarding the quality of service for the application. The quality of service may have two indicators: the learning proficiency of students and the capability of the application to classify students according to their accumulated knowledge.

A statistics page is also available. It displays the number of users that entered the application, the total number of students, and the number of students with and without activity, as well as other information that gives an overall view on the activity on the application.

Secretary users manage sections, professors, disciplines and students. On any of these a secretary may perform actions like add, delete or update. These actions will finally set up the application so that professors and students may use it. In conclusion, the secretary manages a list of sections, a list of professors and a list of students. Each discipline is assigned to a section and has as attributes a name, a short name, the year and the semester of study when and the list of professors teaching the discipline which may be of maximum three. A student may be enrolled to one or more sections.

The secretaries have also the task to set up the structure of study years for all sections. They have the possibility of searching students using different criteria like name, section, year of study or residence. The secretaries have a large set of available reports regarding the student's status. Among them there is a list of students who took all the exams, a list of students who requested grants for taking an exam one more time and many other reports specific to secretary work.

The main task of a professor is to manage the assigned disciplines while the discipline is made up of chapters. The professor sets up chapters by specifying the name and the course documentation. Only students enrolled in a section in which a discipline is studied may download the course's document and take tests or examinations. Besides setting up the course's document for each chapter, the professor manages test and exam questions. For each chapter the professor has to define two pools of questions, one used for testing and one used for exams. He specifies the number of questions that will be randomly extracted to create a test or an exam. Let us suppose that for a chapter the professor created 50 test questions and 60 exam questions and he has set to 5 the number of test questions and to 10 the number of exam questions that are to be randomly withdrawn. It means that, when a student takes a test from this chapter, 5 questions from the pool of test questions are randomly withdrawn. When the student takes the final examination at the discipline from which the chapter is part, 15 questions are randomly withdrawn: 5 from the pool of test questions and 10 from the pool of exam questions. This way of generating tests and exams is intended to be flexible enough for professor.

All tests and exams are taken under time constraints. For each chapter the professor sets up a number of seconds necessary to answer questions of that chapter. When a test or exam is taken all the seconds are summed up thus obtaining a maximal interval of time in which the student has to finish the test. The elapsed and remaining time are managed by the server and presented to the student after each answered question.

The professor has also flexibility for creating and editing questions. A question may contain pictures, and thus equations, formulas or other graphics may be imbedded in it. For each question the professor sets up the visible answers and the correct answers. There are two implemented formulas that may be used for calculating grades. For each discipline the professor chooses and sets any of the formulas such that it will be used for all tests and exams taken at that discipline.

Professors have also the possibility of searching students using different criteria and a large set of available reports that help them in working with students.

The application offers students the possibility to download course materials, take tests and exams and communicate with other parties involved, as professors and secretaries. Students may download only course materials for the disciplines that belong to sections where they are enrolled. They can take tests and exams with constraints that were set up by the secretary through the year structure function.

Students have access to personal data and can modify them as needed. A feedback form is also available. It is composed of questions that check aspects regarding the usability, efficiency and productivity of the application with respect to the student's needs.

All users must authenticate through username and password. If the username and password are valid the role of the user is determined and the appropriate interface is presented. The platform assigns a set of actions that the user may perform. Each time a user initiates an action the system checks if that action is allowed. This approach ensures security at user's level and makes sure that a student may not perform actions that are assigned to professor, secretary or sysadmin users.

A record of sustained tests is kept for all students. In fact, the taken test or exams are saved in full for later use. That is why a student or a professor may view a previously taken test or exam if needed. For each question is presented what the student checked, which was the correct answer, which was the maximum score that could be obtained from that question and how many points did the student obtain. At the end it is presented the final formula used to compute the grade and the grade itself.

Besides these core functions for the on-line testing some other are implemented or currently under development. A message board is available for professors, secretaries and students to ensure peer-to-peer communication. This facility is implemented within the platform such that no other service (e.g. email server) may be necessary.

2.2 Imagistic Digital Library

Further on, this paper presents the way in which a medical imagistic library is managed for educational purposes. This implies the insertion of images and the launch into execution of some pre-processing algorithms for extracting information related to color and texture, as well as the significant color regions. Thus the images are prepared for the next stage, which is that of content-based query by color and texture.

Database Structure and Management. The system offers professors the possibility to insert new images in the database, together with their relevant information, namely: path and name of the image file, the diagnosis, as well as supplementary information that include specialists' observation regarding the disease and the way in which it is illustrated by image, treatment and evolution**.**

For realizing the content-based visual query, all the images loaded in the database are automatically processed, in three steps:

- the extraction of color feature
- the extraction of texture feature
- the extraction of significant color and texture regions

The extraction of color feature. The images are pre-processed, namely they are transformed from the RGB color space to HSV color space and quantized to 166 colors, being thus prepared for a future query. The HSV color space is preferred, for its properties (compactness, completeness, naturalness and uniformity) which allow it to be proper for usage in the content-based visual retrieval [13], [17].

For the quantization of the HSV color space, the solution with 166 colors was chosen. Because the hue represents the most important color feature, it needs the finest quantization. In the circle that represents the colors, the primary colors red, green and blue are separated by 120 degrees. A circular quantization with 20 degree step separates sufficiently the colors. The saturation and the value are each quantized to three levels. The quantization produces 18 hues, 3 saturations, 3 values and 4 greys, that means 166 distinct colors in the HSV color space. The color information from the image is represented by means of the color histogram and by the binary color set. The color information is stored in the database as a vector with 166 values and it is used furthermore in the content-based image query and content-based region query [13].

The dissimilitude between the query and target image is computed using the histogram intersection [13], [17]:

$$d_{q,t} = 1 - \frac{\sum_{m=0}^{M-1} \min(h_q[m],\ h_t[m])}{\min(|h_q|, |h_t|)} \quad \textbf{(1)}$$

The extraction of texture feature. Together with color, texture is a powerful characteristic of an image, which is present in nature and in medical images also. Thus a disease can be indicated by changes in the color and texture of a tissue [15].

There are many techniques used for texture extraction, but there is not any certain method that can be considered the most appropriate, this depending on the application and the type of images taken into account. The effectuated studies on medical images indicated that among the most representative methods of texture detection are the

Gabor representations, reason for which it was chosen for extracting the colour texture feature from medical images in the database [15].

In the case of Gabor filters, starting from the representation of the HSV colour space, the colour in complex can be represented [14], [16]:

$$b(x, y) = S(x, y) \cdot e^{iH(x, y)} \quad (2)$$

The computation of the Gabor characteristics for the image represented in the HS-complex space is similar to the one for the monochromatic Gabor characteristics, because the combination of colour channels is done before filtering [14], [16]:

$$C_{f,\varphi} = (\sum_{x,y} (FFT^{-1}\{P(u, v) \cdot M_{f,\varphi}(u, v)\}))^2 \quad (3)$$

The Gabor characteristics vector is created using the value $C_{f,\varphi}$ computed for 3 scales and 4 orientations [16], [18]:

$$f = (C_{0,0}, C_{0,1}, \ldots, C_{2,3}) \quad (4)$$

So the texture feature is represented for each image as a 12-dimension vector stored in the database.

The dissimilitude between the texture characteristics of the query image Q and the target image T is defined by the metric [14], [16]:

$$D^2(Q,T) = \sum_f \sum_\varphi d_{f\varphi}(Q,T), \textit{where } d_{f\varphi} = (f^Q - f^T)^2 \quad (5)$$

Extracting the color regions. For detecting color regions, it was chosen the color set back-projection algorithm, introduced initially by Swain and Ballard and then developed in the research projects at Columbia University, in the content-based visual retrieval domain [13]. This technique provides the automatic extraction of regions and the representation of their color content. The extraction system for color regions has four steps [13]:

1. the image transformation, quantization and filtering (the transformation from the RGB color space to HSV color space and the quantization of the HSV color space at 166 colors)
2. back-projection of binary color sets
3. the labeling of regions
4. the extraction of the region features

The color regions detected by applying this algorithm on each medical image are stored in the database with the following characteristics: the color set, the area (the number of pixels) and the minimum-bounding rectangle that bounds the region. All this information is used later in the e-testing process that uses content-based region query.

Medical Imagistic Database Query for Learning Purpose. The medical imagistic database can be visualized by browsing the images and their attached information, or can be simply queried by text. For example, the student introduces a diagnosis and the images included in the specified diagnosis will be returned from database.

A more modern solution is that of an imagistic database query based on content. This supposes that there are not keywords or other textual information, but only an image is chosen from database, and the system will return a number of images similar with the query image taking into consideration the following characteristics: color, texture or shape automatically extracted. This process is called content-based image query [13], [17].

The retrieval can be done also by taking into consideration the significant color regions automatically detected from color medical images. A relevant region that indicates the existence of a disease is selected, and the system will retrieve a number of relevant images, meaning images that contain a similar region with the query one.

The student can analyze a lot of images from the same diagnosis, he can see the changes in color, texture or shape of the seek tissue reflected in the image. The content-based visual query offers to the student a variety of options, raises his curiosity, because the student can select any image from the database and the query response can be different because the database is permanently updated.

Content Based Image Query Based on Color and Texture Features. It requires the selection of an image as a query image and the retrieval of all those images from database which best resemble it, taking into consideration the color and texture features, each in equal parts. Also, for every image detailed information is displayed.

Content-based visual query is a searching method based on similarity and not on the equality. It will return images visually similar with the query image, with the same diagnosis, or different diagnosis. For computing the dissimilitude between a query and a target image from database, the color characteristic (represented by a 166 values vector) and the texture characteristic (represented by a 12 values vector), in equal weights were considered. The color dissimilitude is calculated using the equation 1, and the texture vectors dissimilitude using the equation 5. The overall distance between the query and target image is the average of these two values. The images are displayed to the student in the ascending order of the computed dissimilitude.

Content-Based Region Query. It is necessary to select an image and to display the color regions detected with the color set back-projection algorithm. Next, the user must tick one or more color regions for content-based region query. The result is a set of images from the database that contain the query region(s), based on ascending order of the computed distance. Taking into account that the color information of each region is stored as a color binary set, the color similitude between two regions is computed with the quadratic distance between color sets [13]:

$$d_{q,t} = \sum_{m_0=0}^{M-1}\sum_{m_1=0}^{M-1}\left((s_q[m_0]-s_t[m_0])a_{m0,m1}(s_q[m_1]-s_t[m_1])\right) \quad \textbf{(6)}$$

The window in figure 1 displays the images containing the regions on which the database query was made.

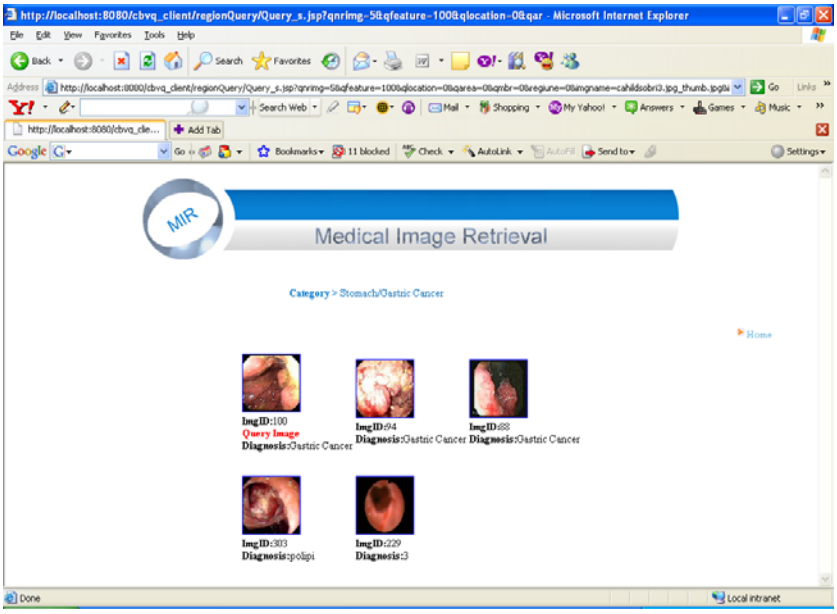

Fig.1. The results of the content-based region query

e-Testing Solutions based on the Medical Imagistic Database. The medical imagistic collection and content-based visual query can be used in e-testing also. The original e-testing solution proposed in the TESYS platform, can be done in two different ways:

- using content-based image retrieval
- using content-based region retrieval

In the first case, the testing process is the following: an image from the database that represents the query image is displayed. The student is asked to establish the diagnosis and to give details that will be added in text type controls. The "Content-based Image Query" option should be activated next. The content-based image query system will return a number of images from database that can be relevant or non-relevant for the query. For each image retrieved by the system, the student has to establish if this is relevant or non-relevant for the query image, meaning the image is or not included in the same diagnosis. The number of similar images retrieved automatically by the system can be established by the teacher before the testing (for example between 5 or 10 similar images). Also, the teacher has the possibility to establish the number of images on which the testing is done and to what diagnosis they belong.

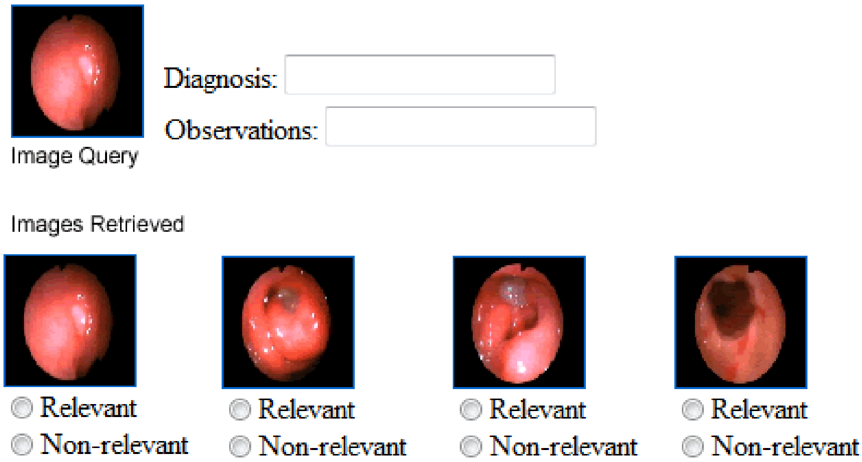

Fig. 2. An example of e-testing using the content-based image query on medical imagistic database

The utilization of this testing system for medical hybrid learning shows that such testing environment is recommended to contain 3 query images and for each of them to be retrieved 5 similar images. This modality keeps students interested and offers the teacher a good idea about their capacity to accumulate knowledge necessary to establish a correct diagnosis for certain patology.

At the end of the test, the student will be automatically marked. He will receive the corresponding mark for each relevant image retrieved (the relevance is automatically established based on diagnosis) and also the correct diagnosis from the database and other information introduced by teacher will be displayed. Also, the student can visualize the correct solution of the test. This way, he can observe his errors and understand why images similar by color and texture are included in different diagnosis.

The electronic testing that uses the content-based region query comes to complete the first modality of testing. This is considered more complex, because a fine granularity approach to image retrieval is adopted. The student's testing takes into consideration the relevant color/texture regions automatically detected from medical images. The student has to select the option 'Regions Detection' and the relevant regions will be detected automatically by the system. In general, in an image there are many normal regions (healthy tissue) and a single relevant region for the diagnosis, which presents changes in color and texture in comparison to the normal one; the student has to recognize the abnormal region in the image. After that, the student has to mark the corresponding region and select the option "Content-based region query", which will retrieve a number of images from database (5 up to 10), that contain regions similar to the query region. The student has to establish which images from the images automatically retrieved by the system are relevant for the query region. Also, in this case, the student is automatically marked, getting the points for each relevant region recognized, relevance established based on the image diagnosis from the database and can visualize the correct results.

3 Conclusion

The paper presents in detail the functions of an original platform for medical e-learning that completes the traditional way of performing this activity. The implemented platform creates an environment in which students can take tests or exams at different disciplines.

As an original element, the implemented system offers students a multimedia medical database that apart from the traditional information also contains medical images. Within the learning process, the image database can be consulted in a modern way, image or region-based manner.

The paper also presents an e-testing modality of students from medical domain that uses the same database and the two modern query methods.

The medical imagistic collection and content-based visual retrieval used in the training and e-testing processes help to increase the students' ability to find the correct diagnosis and to choose between very similar images as color and texture, but that are included in different diagnosis, reducing the probability for the future physician to establish a wrong diagnosis, which may have serious consequences on patient's health.

For each kind of pathology, the teacher can determine the student's level of knowledge and also, at general level, the student's capacity to establish a correct diagnosis based on the imagistic investigations, frequently used nowadays.

The solution of teaching and e-testing using content-based visual query in a database with medical images is used in parallel with traditional techniques at the University of Medicine and Pharmacy. During the year 2007, 60 students used the e-training module based on imagistic database and content-based visual query in study of the gastroenterology discipline. Each of them accessed the database for approximately 9 times, spending in average 200 minutes.

The 60 students participated also at the electronic testing, using the imagistic database and content-based visual query at the same discipline. It was recorded an improvement of the correct established diagnosis number based on medical images. In 2006, when this multimedia component was not used, the average number of images correctly analyzed and diagnosed was 5 from 10, and in 2007, using the multimedia database, was obtained an average of 7. This improvement, in such relative short time (one year) clearly indicates that this modality can bring important benefits in raising the student education. Of course, this development can be influenced by other factors (the intellectual capacity of the students, for example), so the system efficiency must be observed for a longer period of time.

The students found it attractive, innovative, and with big advantages in testing the level of achieved knowledge.

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