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**THE POTENTIAL APPLICATION OF REGION MARKING SOFTWARE TOOL IN  
MEDICAL DIAGNOSTIC EDUCATION**

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**Abstract:** *Region Marking Software Tool is used in the first phase of ROC evaluation for data gathering. In this paper we will demonstrate that this software tool can be adopted, with modifications, as a software platform for education in medical image diagnostics. Specifically, diagnostic tasks are performed the same way in both ROC evaluation and medical image diagnostic education. We will present a prototype software tool built upon our Region Marking Software Tool. As it is based on web technologies, this software tool is suitable for presence and distance education and training in medical image diagnostics.*

**Keywords:** *E-learning, E-health, Diagnostic Imaging Education, ROC evaluation, medical image quality*

## **I. INTRODUCTION**

There is undisputed need for training (and educating) medical students (and professionals) in imaging diagnostics [8]. One of the best ways to achieve this is by tutorage on real case examples. Senior specialist (clinician) is guiding a student through a diagnostic task on a series of medical images. Student is marking hers/his findings on real case medical images. The marking could be supervised or independent. Each case is then discussed separately.

Although appealing, this is a highly unlikely scenario. Or at least, it is highly unlikely for a long period of time. There is always a shortage of available clinicians. Their schedule has few openings. It is hard for them to devote their time to train the others. The best they can provide is several meetings. Also, the tutorage scenario achieves the best results when applied to one student, which is, also, highly unlikely. Usually, the students are tutored in groups. This effectively limits the number of cases evaluated and the training received. In the other hand, this approach has its benefits, because it stimulates group discussions and work.

Tutorage scenario is usually supported with (or replaced with) classical lectures in a classroom. Everything is, usually accompanied with practical demonstrations. Students participate in the everyday clinical practice as spectators. They observe clinicians' work. Usually they get the opportunity to discuss the findings.

All this leads to a conclusion that it is necessary to back the whole training program with additional tools which will give students more opportunities to practice and learn. Software tools are good solution [8]. It is possible to design a software tool to simulate diagnostic task. User is presented with a medical image which should be evaluated. The evaluation results are compared to a gold standard defined by senior clinician (or board of clinicians). The comparison is presented to the user. Each of the findings on the image is extensively explained. The number of studies available to the user is limited only with the size of the medical image database. Also, it is possible to implement the

program to support presence and distance training equally. Distance training could be upgraded to support online CSCL (Computer Supported Collaborative Learning). Users could share their knowledge, evaluate images together, and discuss their results. It is possible to schedule special events held by senior clinicians.

The software solution could be developed from the scratch or a similar product can be used and adjusted for the educational purpose. In this paper we will demonstrate the potential applicability of Region Marking Software Tool in medical diagnostic education and training. The Region Marking Software Tool is used in data gathering phase of ROC evaluation.

In medical imaging, quality is evaluated using subjective ROC evaluations [11]. The results are usually quantified using ROC analysis [1]. The evaluation is conducted in two phases: *data gathering* and *data analysis* [6]. In the *data gathering* phase qualified observers perform diagnostic tasks by marking regions of interest. A region marking software tool is used for data gathering. Statistical data extracted from these markings are used for medical image evaluation in the *data analysis* phase of ROC evaluation. Medical image influence on diagnostic accuracy is evaluated by measuring whether the same results are achieved compared to some gold standard [2].

Diagnostic tasks are performed the same way in both ROC evaluation and medical image diagnostic education. The difference occurs in later stages. Background of the research is described in Section 2. We will present a prototype for software tool built upon the Region marking software tool in Section 3. Section 4 concludes the paper.

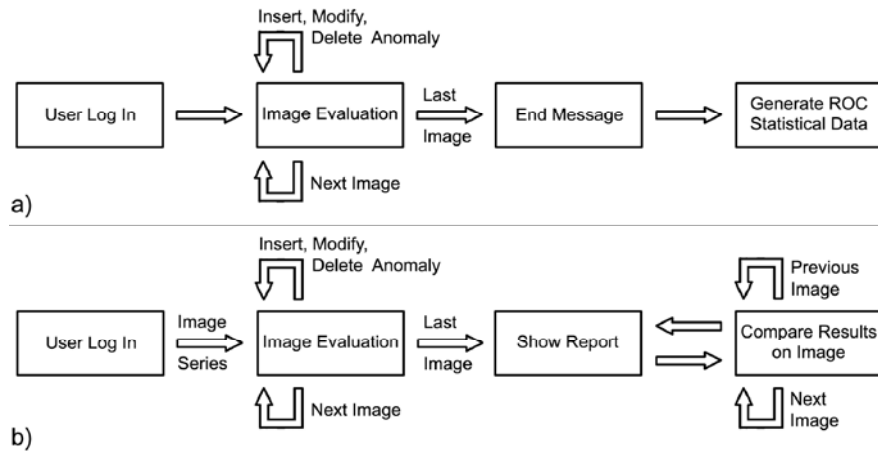
## II. BACKGROUND

We are developing a quality evaluation system for compression of still images in PACS systems (Picture Archiving and Communication System) [5, 7]. We found that in order to measure the quality of a compression technique used in PACS, it is invaluable to perform subjective quality evaluation of medical images. As the ROC evaluation is a norm in evaluation of medical images, we decided to include it in our evaluation system. In the *data gathering* phase of the ROC evaluation, it is necessary to use software tools for tracking observers' performance. However, it is very difficult to base the ROC evaluation on software tools used in every day clinical task [6]. In everyday clinical task, when clinicians perform diagnostic task, they only mark region of interest on the medical image. They do not provide their rate of confidence. In most cases they additionally describe the anomaly (size, characteristics, etc). They do not report that their rate of confidence is some number (i.e. 4). In the ROC evaluation, confidence rate is described in number array ranging from 1 to 5 where 1 means low confidence and 5 means high confidence [2]. Software tool used in everyday clinical practice do not provide confidence rating, thus it is necessary to use or develop additional software which is more suitable to the ROC evaluation. When observer marks the region of interest, she/he should be able to simultaneously provide the confidence rate.

In the case of our quality evaluation system, we did not manage to find any software tool which is free and suitable for *data gathering* phase of ROC evaluation. Therefore, we implemented it ourselves. We based our solution on HTML (Hyper Text Markup Language), PHP [10], JavaScript [12] and MySQL [9]. These web technologies are suitable for our software tool. When designing this software tool we had following requirements: we wanted to use free technologies, we wanted to build graphical user interface similar to the ones used in everyday clinical practice and we wanted to support remote evaluation. The reasons we used web technologies are described in detail in [6]. The software tool is executed in side a Web browser.

Application diagram for the Region Marking Software Tool in the ROC evaluation is described in Figure 1.a. It is necessary to authenticate the users (observers), because the Region Marking Software Tool is not used in a controlled environment. Only when the observer is authenticated, she/he can proceed to image evaluation. Due to the nature of the ROC evaluation, observers are limited to only one medical image series at a time [6]. When observer finishes the image series, the next one is available to her/him only after some time. Each medical image of the series is evaluated separately. During evaluation, observer can mark, modify and/or delete one or more regions

of interest with no limitations. However, when evaluation proceeds to the next image, it is not possible to change the markings made on the previous images. It is possible to proceed to the next image without making a single mark. That means that no anomaly has been detected on the image.



**Figure 1.** The Region Marking Software Tool – application diagram: a) ROC evaluation version; b) educational version

Also, observers can stop the evaluation at any time. Each evaluation starts either from the first image in the series or from the last one evaluated. After the last medical image is evaluated, ROC statistical data are generated. These data are not reported back to the observer. The observer is only informed that the evaluation of that series of medical images ended.

### III. PROTOTYPE OVERVIEW

In the design phase of the Region Marking Software Tool, we noticed that the software tool is also suitable for education and training in medical imaging diagnostics. Of course, it is not possible to use the software tool as it is. But with some modifications, it can be adopted for educational purposes. Its biggest strength lies in the fact that it already supports remote evaluation, so it is suitable for distance learning. The main difference in educational use and ROC evaluation is that the results are not used to evaluate the medical image but the observer’s performance and knowledge. Therefore, it is not only possible but mandatory to report the results back to the observer. In this paper we are demonstrating that only basic modifications of the software tool are necessary to make it usable in education, but they are not enough to convey the best education.

Initially (as we described it in [6]) we wanted only to improve the software tool and to make it usable both in education and the ROC evaluation. In this scenario the software tool would have two modes of operation: ROC evaluation mode and educational mode. Thus, when observer starts the application, it is necessary to decide the mode of operation. However, the primary goal of the operation is the ROC evaluation. The restrictions of the ROC evaluation could limit the efficiency of educational version and educational value of the software tool. Therefore, we decided to build new software tool based upon the Region Marking Software Tool which will be specifically used for education. We wanted to build a prototype which will modify the original version of the software tool in the smallest possible way. The primary reason behind the fast prototype design is to get the results as soon as possible. We wanted to test our ideas, to see whether we overlooked some aspects of the educational version, and whether some significant modifications are necessary for the final version.

As it is shown in Figure 1.b, application diagram of the prototype is very similar to the version used in the ROC evaluation. The first two steps are similar to the steps of the ROC evaluation. Observers have to authenticate themselves. This is necessary for the remote access support but it is also necessary for tracking the history of the results. Answers could be linked to the observer for the

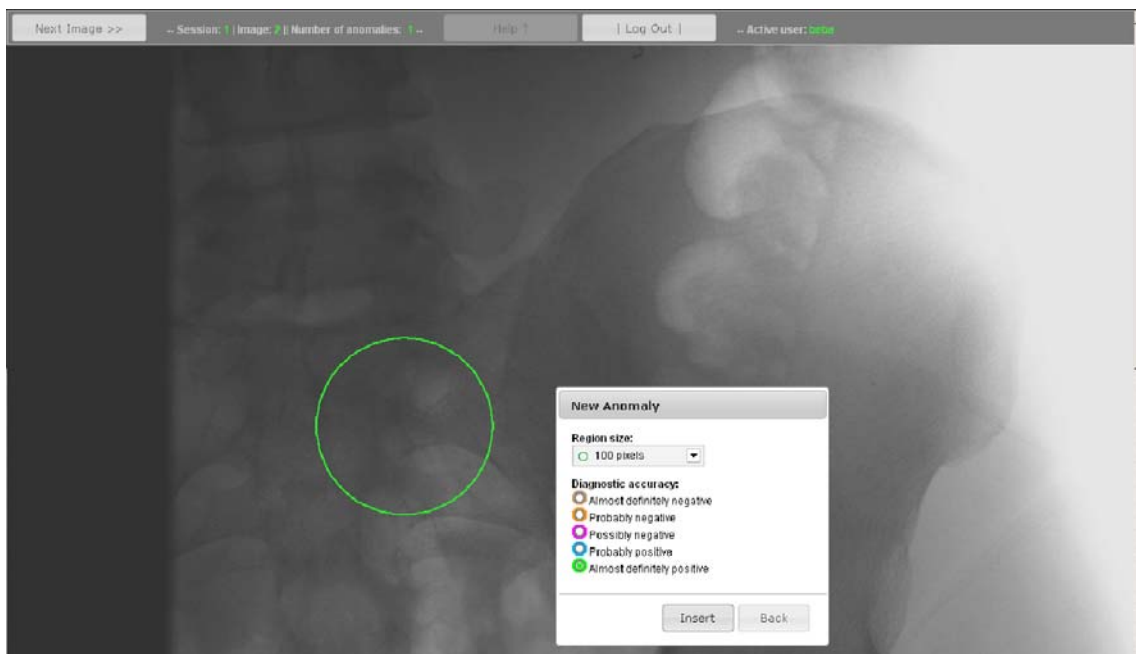
purpose of performance evaluation and tracking. That way, observers could track their progress, they could compare the results, and they could see how much did their skills improve. The tracking of the observer's progress is intended for the final version of the education version of the software tool.

Medical images are evaluated in the same manner as in the ROC evaluation. However, we immediately noticed that there should be no limitation on medical image series. Each of the series is accessible right from the start. A selectable list of available series is presented to the observer. The prototype retains some limitations of the original software tool. Once that medical image series is chosen from the presented list, observer has to finish the evaluation of all images in the series. It is not possible to move freely between the images. When evaluation proceeds to the next image, it is not possible to return to the images previously evaluated. However, it is possible to stop the evaluation at any given moment. The next time, the observer continues the evaluation from the last image evaluated.

Contrary to the ROC version of the software tool, when evaluation ends, the observer's results are compared to the gold standard (correct answers), and a report is generated. There would not be much use of the software tool if only the textual comparison of the results is provided. In that case, observers will only found out how many correct answers they had, but without an explanation and example given. This would have an insignificant educational value. It is necessary to compare the results on an actual image. Therefore, it is possible to display each of the images evaluated containing the observer's marks compared to the gold standard. Each answer from the gold standard is explained in line with the clinical decisions made. At any given time users can view the previous or the next image, without restrictions. During all that time, Report page is always available.

Both prototype and the original version of the software tool are implemented in Serbian language. However, it is possible to change the language in PHP configuration file. For the sake of the presentation, we replaced Serbian labels with English.

After observer's authentication and medical image series election, the medical image evaluation page is presented to the observer, Figure 2.

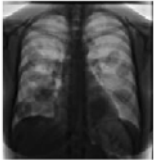
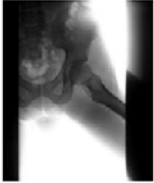


**Figure 2.** Medical image evaluation page

Regions of interest are marked by left clicking on the image. Due to the limitations in implementation of the original version of the software tool, observers cannot define custom sized/shaped regions of interest. It is necessary to choose some of the predefined region sizes. We intend to address this limitation in the final version of the software tool. The region size and confidence rate are defined in a dialog, Figure 2. Dialog actions result in a circle drawn around the anomaly. It is drawn in the selected size and the color corresponding to the degree of certainty. If

observer wants to edit the region of interest, she/he has to click on it and to define new values through a dialog similar to the one from Figure 2. This dialog has an option for deleting the mark. Multiple anomalies can be marked on the same image, but overlapping is not allowed. Evaluation is stopped by clicking the *Log Out* button. Transition to the next image is achieved by clicking on the *Next Image* button.

After the last medical image of the series is evaluated, the observer is presented with the Report page, Figure 3. The page contains short statistics of the marked answers (numbers of the correctly and falsely marked anomalies) and gold standard (the correct number of anomalies in the image). Each image is represented with a thumbnail. The observer can view the answers compared to the gold standard for each of the images by following the corresponding link, Figure 3.

Image		Answers		Gold standard	Link
Thumbnail	ID	Correct	False		
	P6_1_1	1	2	3	<a href="#">Show PG 1 1</a>
	P6_1_2	0	1	2	<a href="#">Show PG 1 2</a>

**Figure 3.** Report page for medical image series evaluated

Printing of the Report page is not supported within the prototype. However, it is possible to use the printing option of Web browser. Also, we did not change the structure of the database underlying the prototype. Therefore, a history of the observers' results is not kept in the database. New evaluation of the same medical image series will overwrite the old results. This is a limitation which will be corrected in the final version of the educational software tool. We will modify the database for long term storing of the observer's results for future references. A new option will be implemented to enable the observer to overview, compare and print hers/his results.

The observer's answers are compared to the gold standard on a page similar to the one described in Figure 2. Two types of circles are drawn. The observer's answers are drawn in the color corresponding to the degree of certainty. Red color is used for drawing circles corresponding to the gold standard. If the observer's answer overlaps the gold standard completely, both circles are drawn around the anomaly. The red circle, of the gold standard, frames the observer's answer. If the observer left clicks on the circle of the gold standard, an explanation of the clinical decisions is shown in a separate dialog. If the user left clicks on the circle corresponding one of the answers, the chosen degree of certainty is shown and explained in a separate dialog. User can always proceed to the next or previous image in the series. Also, the Report page is always available. During this time, observer can start evaluation of new series of medical images. In contrast to many ROC evaluation systems there is no time limit for evaluation [2]. However, new evaluation makes the Report page and the old results unavailable.

The prototype demonstrated some limitations which are consequence of the ROC evaluation. The prototype is only suitable for education and training, but to make an efficient educational tool with high education value, it is not possible to simply extend the Region Marking Software Tool. It is necessary to introduce some deviations from the original software tool and to adopt new design directions. Contrary to the ROC evaluation, there should be no limits on the availability of medical images. Therefore, after current evaluation ends, users should be able to continue to the next series of

medical images without restrictions. There should be no limitation on moving back between the images evaluated. It should be possible to repeat an evaluation unlimited times. A history of observers' results should be kept in the system. At any time, the observer should be enabled to see, not only the reports, but the old results visualised on the actual medical images. Also, there should be an option to compare the old and new results, and to print them.

#### IV. CONCLUSION

In this paper we described the potential applicability of the Region Marking Software Tool in medical diagnostic education and training. It is possible in a simple way to modify the software tool for the educational use. We demonstrate this with the prototype based on our software tool. It is developed using web technologies such as HTML, PHP, JavaScript, and MySQL. The system's sole requirements are internet access and a web browser that supports the necessary standards, a condition easily met by any modern web browser. The prototype enables execution of simple diagnostic tasks on medical images. In later stages of the evaluation observers' answers are compared against the gold standard (the correct clinical decisions) which is defined by senior clinicians. The comparison is visualized on the actual images. Also, the report is generated.

Development of the final educational version of the software tool is still in progress. Also, clinical trials are necessary to test the usefulness of the proposed solution. However, the prototype demonstrated that it is necessary to make deviations from the original software tool in order to make it more appropriate for the education and to increase the educational value of the software tool proposed. Most important of them is the tracking of the observers' results for the future references. This will be introduced in the final version of the educational software tool.

Several accessories are planned for the final version. We intend to support marking of custom sizes/shaped region of interest. To avoid problems in handling a MySQL database that requires some computer skills and that has a license limitation, we intend to expend data management to XML (Extensible Markup Language). XML files will be used as an alternative to a MySQL database. This would make the solution completely free and we will be in opportunity to make it freely available on the Internet.

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