Radboudumc

Intelligent Systems in Medical Imaging

Assignment 4

Evaluation and ROC analysis

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Please send the answers to questions and some screenshots of your results to:

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Task Overview:

In this computer assignment you will train your knowledge about evaluation of detection methods, by applying prepared assessment tools. All these evaluations are performed on diagnosis of nodules in lung X-ray images, which in fact is a tricky diagnosis task, as you will soon experience!

First you will get acquainted with the concept of lung nodules: You will see 15 training cases of the X-ray image, then you will observe how a non-ideal computer-aided diagnosis (CAD) system detects some suspicious candidates of lung nodules. Finally ground truth annotated by experts is exposed for your consideration.

After the training phase, it is time to go right into the problem and maybe discover your hidden intelligence in detecting lung nodules! You will be presented with 60 cases which may or may not contain lung nodules: for each case you should judge the certainty of existence of a nodule and enter this certainty in an excel file in a specified format. Then you will see the assessment of the CAD system that may change your opinion. You must enter your new evaluation after observing CAD in your excel file as well.

After you are done with detecting and scoring lung nodules, you have to perform ROC analysis to compare your performance alone, your performance assisted by CAD and the performance of the CAD system alone as well. For this purpose you will use JAFROC which is a software for performance analysis.

Please note that for training and detection phase you will use the E-Learning workstation which at this time is only available for Windows OS. You will use a Windows virtual machine in this assignment.

1 Training and Detection

Description: In this subsection, first you will see 15 cases to familiarize yourself with chest X-rays and the CAD system. Please note that these cases are sorted in an ascending order in terms of difficulty of cases. Do your best to learn as much as possible in this phase because later for detection you will not see ground truth annotations.

1.1 Workstation Setup

Please follow these instructions:

1. Find "runELearningWorkstation.bat" in `C:\STUDY\el131112_steven\` and run it.
2. Get username and password for login from TAs.

1.2 Training

Solitary pulmonary nodules are incidental findings on chest X-ray or computed tomography (CT) images. These nodules are round shaped and smaller than $3cm$ in diameter. They may represent early lung cancer, and prompt detection and treatment may improve clinical outcome.

To get a sense of lung nodule detection complete the following steps:

1. Choose *Training Practicum CAD* item (and select it again for the second time!)
2. Starting from check list 1, you will see the X-ray image of the first training case. Try to find where you see a suspicious abnormality.
3. Press *Continue* to see the detection results of the CAD system. Note the probabilities marked on each candidate. Also note that to get a better view of the detected candidates, you can press c key to toggle the CAD marks on and off.
4. Press *Continue* to see the ground truth. Please note that CAD will not necessarily find suspicious lesions in all cases and that some cases may be normal and thus do not have nodule annotations.
5. Iteratively go through different cases and try to generalize characteristics of nodules you observe to come up with an idea how lung nodules look like.

1.3 Lung nodule detection

After you are done with training cases perform the following steps:

1. In the *Courses* tab select the item *Study practicum CAD* and select this item once more in the next page.

2. Open the template excel file provided for you called "scores.csv". You can find this file in "jafroc" folder on desktop of the virtual machine. You have to provide your assessment on whether there is a nodule present in the image or not, inside this file by following a specified format.
   To be able to evaluate your diagnosis, carefully read the description for this format. In this file you will find 3 columns: *CaseIndex*, *ModalityID*, and *Score*. For each case you need to put 3 rows:

   (a) **Your detection without CAD**: Use case number for the *CaseIndex* field, 1 for the *ModalityID*, and a floating number between 0 and 1 indicating the likelihood that a nodule is present in the image for the *Score* column. The given score can be zero meaning you believe there is no nodule in the image.

   (b) **Your detection given CAD results**: You may change your opinion given CAD detections. In a similar manner fill **CaseIndex** and **Score** fields, but use 2 for the *ModalityID*.

   (c) **CAD system detection**: Put 3 for the *ModalityID* field. In the case there are several nodule candidates, consider the most probable candidate for *Score* field.

   For better illustration of how you should fill this excel sheet ("scores.csv"), see the sample partial table shown in figure 1.

3. Go iteratively through different cases. Each case has 2 images:

   (a) After seeing each X-ray image (before taking a look at CAD system), fill the first row as described above for your detection.

   (b) Proceed to CAD detection image and fill the second row with your opinion influenced by CAD system. Remember you can toggle CAD marks on and off with the *c* key.

   (c) Fill the third row with the highest CAD score in the image.

	A	B	C
1	CaseIndex	ModalityID	Score
2	1	1	0.11253
3	1	2	0.795485
4	1	3	0.491535
5	2	1	0.945612
6	2	2	0.592259
7	2	3	0.401382
8	3	1	0.753668
9	3	2	0.234489
10	3	3	0.418106

Figure 1: A Sample showing the way data in scores excel sheet should be filled.

2 ROC analysis with JAFROC

Complete the following tasks and answer the questions:

1. JAFROC requires getting the detection information in a certain format, which is a little bit more complex than what you created as “scores.csv’. In order to simplify your task we have written a program that given your excel file generates the excel file in JAFROC format. Find “JafrocInputGenerator.exe” in the same folder “jafroc” on desktop. Note that “scores.csv” must be located in the same folder. Now run the exe file and mind the output to see if there has been any error.

2. If there were no problems with your excel file format, you will find three new excel files called “tp.csv”, “fp.csv” and “truth.csv”. What you need to do is to merge them to a single .xls file. In the same folder, find and open “jafrocInput.xls” which is an empty xls file with three sheets named the same as your three .csv files. Copy content of each .csv file into the corresponding sheet in “jafrocInput.xls”.

3. Run JAFROC from the start menu of Windows in VM. From the file menu of the JAFROC software click on *select Data File*. Select the input excel file named “jafrocInput.xls” you just created. Assuming the selected file did not generate errors, a summary of the imported data will be displayed.

4. To get an objective measure of the observer performance, you will conduct ROC analysis. The area under the ROC curve (AUC) is a com-

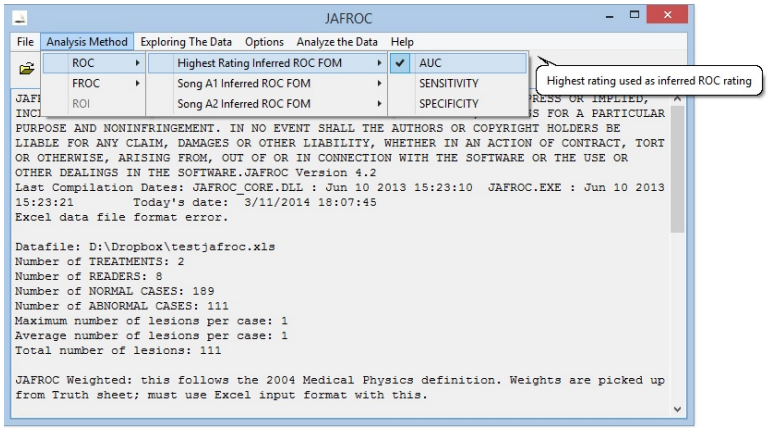

Figure 2: JAFROC interactive environment.

monly used figure-of-merit in ROC analysis. Select *Inferred ROC* for your ROC analysis method as shown in Figure 2. This item uses the highest rating on an image as the equivalent ROC rating of that image. Click on *Run* in the *Analyze the Data* menu. This will generate a report file in the directory where the imported .xls file was located.

5. **(Question 1)** Look at the generated txt file including the ROC analysis results. Which observer has achieved the best performance? Reader, CAD, or Reader+CAD? What is your justification for this?

6. Plot the ROC curve by clicking on: Exploring the *data* >> *Plotting based on selected data file* >> *Empirical plots*. The ROC plot is created by starting with a cutoff at a high value and cumulating events (e.g., true-positives and false-positives) that exceed the cutoff as the cutoff is progressively lowered.

7. **(Question 2)** Looking at the sample result of the CAD system and the ground truth in Figure 3, will CAD detection in the right lung be considered as a true positive or a false positive in ROC analysis? Why? Propose a modification to overcome this shortcoming. Elaborate your answer.

8. **(Question 3)** As a general question far from this assignment, Compare ROC and FROC analysis. Is there any situation in which FROC provides us with some information that ROC does not?

9. **(Question 4)** What would you do to increase the power of the study? Include more cases or more readers?

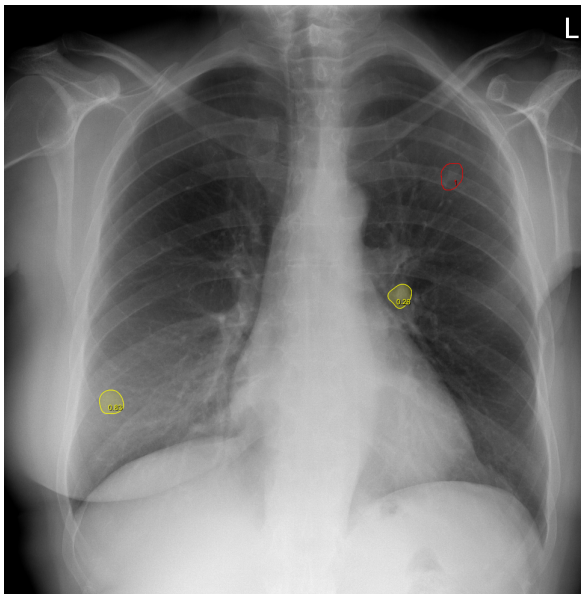

Figure 3: A sample comparison of CAD system detection (yellow annotation) and the ground truth (red annotation).