

Generating Report in Ultrasonographic Diagnostics System SonaRes*

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Abstract

SonaRes is a decision support system for ultrasound diagnostics. The resulting report is the obviously unique result of the ultrasound investigation that can be printed or saved for further reviewing. In this article is presented the structure of medical image report, the methods and techniques for SonaRes report generation.

1 Introduction

Ultrasound equipment is a widespread means of investigation, being available in most clinics in the country even at the district center, it is cheap, effective and rational in diagnostics. In [1] it is substantiated the need for a Decision Support System (DSS) in ultrasound diagnostics, presenting general principles of architecture and operating of such a system.

SonaRes is a decision support system for ultrasound diagnostics which is under development by the scientific team from the Institute of Mathematics and Computer Science of Academy of Sciences of Moldova. This system is targeted to obtain quickly the correct information about specific disease. Especially it will be useful to obtain a second opinion in difficult cases and in emergency [2].

In the first version of our system, our efforts are focused on examination assistance for the abdominal zone (the methodology and

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technology being at the beginning approved on two organs: gallbladder and pancreas). The gallbladder was the first tested organ, which was appreciated by our experts, on the one hand, not so difficult in examination, and on the other hand – the representative enough one. Since in the first place the gallbladder is chosen, the peculiarities are represented on the example of gallbladder, but the general case in the concept concerns any organ.

2 Examination process

An examination process with the assistance of SonaRes system contains the following phases: recording data about the patient, investigation of the patient's organs, generating report.

The phase of patient registration is a simple step. At this step, if the patient's visit is the first one, then the user will enter information about this patient (name, surname, age, address, etc.), but if it is the repeated visit, the user will select the patient data from database. It should be mentioned that this stage can be omitted and the user may proceed with the investigation phase. In this case the examined patient will be considered anonymous.

At the investigation phase one or more organs are investigated. The investigation process of an organ consists of physician's answers to a series of questions by choosing the answer "Yes" or "No" for each of them. Every question is responsible for certain characteristics of the organ. For example, for the characteristics $C1 = "VOLUME\ OF\ THE\ GALLBLADDER"$ we have the following questions $Q1 = "Is\ the\ gallbladder\ normal?"$, $Q2 = "Is\ the\ gallbladder\ enlarged?"$ and $Q3 = "Is\ the\ gallbladder\ diminished?"$.

We described 203 questions for gallbladder. By these questions 54 pathologies and anomalies in this area are described. That is, each pathology or anomaly in the area of ultrasound investigation of gallbladder may be described by vector $(Q1.value, Q2.value, \dots, Qn.value)$, where $Qi.value$ - is the answer to the question Qi , and n - the total amount of questions, in our case $n = 203$. The *value* can have one of three values: "Yes" – if the answer to the question is affirmative,

”No” – if the answer is negative, and ”Any” – if no answer was given to the question. The pathologies and anomalies are presented in the diagnostics base in the form of decision-making matrix $[Pi, Vj.value]$, where Pi – pathology or anomaly, in our case $i = 1\dots54$, $j = 1\dots203$.

By answering to these questions, the user describes the area of ultrasound investigation for given organ, to make the decision for which he needs the assistance of the SonaRes system. The SonaRes system will make a decision for the given case and will display the list of possible pathologies and anomalies, which have been deduced.

In Fig. 1 the investigation interface is presented with an example of the gallbladder investigation.

The screenshot shows the SonaRes interface for gallbladder investigation. On the left, there are two sections labeled 'Repeat 1' and 'Repeat 2', each containing a series of questions and answers. The questions are in green, and the answers are in black. The right side of the interface shows a list of possible pathologies and contradictions, each with a checkbox and a brief description. The 'Multiple Group' label is on the far left, indicating that the repeats are part of a larger group.

Repeat 1

- Is the gallbladder normal (usually: 7-10 cm (with extremes 4-12 cm), anteroposterior and transverse diameter 2-3.5 cm)? - Yes qwe
- Has the gallbladder normal shape (without flexion or instable functional flexion)? - Yes qwe
- Is the gallbladder tonicity normal? C Yes C No
- Is the contour clear? - Yes qwe
- Is the contour continuous? - Yes qwe
- Is the contour regular? - Yes qwe
- Is the image of homogeneous band (linear)? - Yes qwe
- Is the wall with normal thickness: 0.1-0.3 cm, depending on plenitude (fullness)? - Yes qwe
- Are there diffuse intrapancreatic modifications? C Yes C No
- Are there modifications protrusive in lumen (parietal vegetations)? - No qwe
- Are there circumscribed modifications (in the form of transsonic lacunae and reflectogenic inclusions)? C Yes C No
- Is the gallbladder contents normal? - No qwe
- Are there focal modifications of the gallbladder contents? - Yes qwe
- Are the modifications solitary? - Yes qwe
- Are the focal modifications immobile? - Yes qwe
- Do the focal modifications form acoustic effects? - No qwe
- Are the structures eogenic? - Yes qwe
- Have the images mass-like appearance? - Yes qwe
- Are the structures stable? - Yes qwe
- Is the structure homogeneous? - Yes qwe
- Is it localized decline? - Yes qwe

Repeat 2

- Are the modifications solitary? - Yes qwe
- Are the focal modifications immobile? - Yes qwe
- Do the focal modifications form acoustic effects? - Yes qwe
- Does it form acoustic shadow? - Yes qwe
- Is there the posterior reverberation? - No qwe
- Are the structures eogenic? - Yes qwe
- Have the images mass-like appearance? - Yes qwe
- Are the structures stable? - Yes qwe
- Is the structure homogeneous? - Yes qwe
- Is it localized decline? - Yes qwe
- Do you want to describe one more group? C Yes C No
- Are there diffuse modifications of the gallbladder contents? - No qwe

Choose a language: Româna || English Help

Possible pathologies (3):

- R 07. Vesicular biliary lithiasis. Hard calculus (pigmented).
- R 08. Vesicular biliary lithiasis. Soft calculus (pure cholesterol calculus).
- R 09. Vesicular biliary lithiasis. Saltatory

Contradictory pathologies (5):

- R 01. Solitary diverticulum of gallbladder.
- R 011. Multiple diverticula of gallbladder.
- R 02. Hypoplastic gallbladder.
- R 03. Giant gallbladder.
- R 04. Normal gallbladder.
- R 05. Flexion of gallbladder.
- R 06. Gallbladder septum.
- R 09.1 Vesicular biliary lithiasis. Mixed cholesterol calculus.
- R 09. Vesicular biliary lithiasis. Mobile calculus.
- R 09.1 Vesicular biliary lithiasis. Floating calculus.
- R 10. Vesicular biliary lithiasis. Calculus adhered to gallbladder's wall.
- R 11. Vesicular biliary lithiasis. Lodged calculus in the vesicular neck.
- R 13. Vesicular biliary lithiasis. Multiple calculi.
- R 13.1 Vesicular biliary lithiasis. Calculus with gases.
- R 14. Chronic lithiasic cholecystitis.
- R 15. Chronic lithiasic cholecystitis.
- R 16. Acute lithiasic vesicular hydrone.
- R 16.1 Acute lithiasic cholecystitis complicated by empyema.
- R 16.2 Chronic lithiasic vesicular hydrone.
- R 17. Acute lithiasic vesicular hydrone.
- R 17.1. Acute lithiasic cholecystitis complicated by empyema.
- R 17.2. Chronic lithiasic vesicular hydrone.
- R 18. Acute lithiasic cholecystitis.
- R 19. Acute lithiasic cholecystitis.
- R 20. Acute phlegmonous lithiasic cholecystitis.

Figure 1. The screenshot of interface for the gallbladder investigation process.

From Fig.1 it is clearly seen that at the left side we have a set of

questions, the answer to which is "Yes" or "No". To the right we have two lists of pathologies and anomalies. The first list contains pathologies and anomalies described by "questions-and-answers" from the left side of the interface. In the second list, we have the contradictory pathologies and anomalies. In our example, after the description of the area of ultrasound investigation of gallbladder (in the left side of the screen interface), two calculi were found: hard and soft calculus (in the right side of the interface – there are possible pathologies).

In the investigation process there are cases when the user, for description of certain states of the ultrasound investigation area, must answer several times at the same group of questions (in the investigation interface, these groups are separated by a horizontal line). In the example in Fig. 1 it is assumed that there are two types of focal modifications of the gallbladder contents, which means the existence of two types of calculi. To determine what kind of calculi is it, it is necessary to answer to a set of questions for every type of the calculus found (the focal modification). The set of questions is the same for all types of calculi. By answering affirmatively to the question "Do you want to describe one more group?", in the interface will appear a new set of questions of the given group. Depending on the answers for these questions, the system will determine the kind of calculi. The set of questions that can be repeated in the interface, we will name **Multiple Groups**, the questions that are part of these groups we will name **Multiple Questions**. An organ may have several multiple groups. For gallbladder we have the Multiple Groups with questions that describe: diffuse intraparietal modifications, modifications protrusive in lumen, circumscribed modifications, focal modifications of the gallbladder contents, diffuse modifications of the gallbladder contents, etc.

If the user decides that the obtained information in the investigation process is sufficient to make a decision, then he will pass to the phase of report generation.

At the report generation phase (it is the last stage of the examination process) we obtain a structured report, which obviously is the unique result of the ultrasound investigation, which can be printed or

saved for detailed analysis. Thus, the report generation phase is an important stage in our system. In the sequel we will speak about the report generation phase, and namely about the report structure, the methods and techniques for SonaRes report generation.

3 Structured Reporting (SR) of SonaRes

The success of any SR system depends crucially on the completeness of structured report templates, as well as the ability to produce natural language from structured input. An ideal system would create fully structured reports that are consistently organized [3].

Traditionally the medical image report consists of both the well formalized part (patient and image data, digital measurement data) and the arbitrary formed description. We use in reporting the data already collected during diagnostic session [4]. A session contains information about the stages of recording and the investigation of patient.

The SonaRes report is structured in two basic parts:

1. Data for Inquiry;
2. Data for the result of ultrasound investigation.

In the first part of the report there are included data about the patient, the physician and the examination process (date of examination, is the examination the first one or the repeated one).

The second part of the report contains data taken and processed from the investigation process. These data are: a list of questions for which the answer 'Yes' was selected and the list of pathologies and anomalies which were deduced for this case. The investigation result contains two basic parts, which are necessarily included in the report, these are: a) the description of organ and b) the conclusion, and two secondary parts: c) the recommendation and d) the images.

3.1 The organ description

The description - is a text that describes the characteristics of the investigated organ. The text generated for the description depends on

the set of "questions-and-answers" from the investigation process. The questions, the answer for which is negative ("No"), are not used to generate the description of the organ. These questions are not informative in terms of the description of the ultrasound investigation area. The combination of "question-and-answer:negative", is used in the investigation process for deducting the list of pathologies and anomalies, excluding those, whose response for this questions is affirmative ("Yes").

Draw attention to the text of questions from the investigation interface, it is presented in the form of questions, such as Q1 = "Are there focal modifications of the gallbladder contents?", Q2 = "Are the focal modifications immobile?", but for presenting it in the organ description, this text should be processed and in the end to take the following form: "There are focal modifications of the gallbladder contents: immobile". There was a problem in how this text should be processed and presented taking into account that: a) from one question to another the structure of the text may differ, for example, the text for Q1 is QR1 = "there are focal modifications of the gallbladder contents" and for Q2 is QR2 = "immobile", b) our system uses two languages (and more are planned) and lexical structure differs from one language to another. To resolve this problem we concluded that the simplest solution is to process each text of the questions, to include it in the knowledge base. When generating the organ description we will use an algorithm, with the help of which we will unite in the certain order the processed texts for questions from the investigation process. As the result we will obtain the organ's description.

The questions are united in groups. The questions of one group are responsible for one common part of the organ, for example Q1 = "Is the gallbladder normal?", Q2 = "Is the gallbladder enlarged?" and Q3 = "Is the gallbladder diminished?" are united in the group that describes the volume of gallbladder. In this case it will be easier to apply an algorithm to generate the descriptions for each group separately, and in the end, these descriptions will be united in the text.

The organ description will be generated by an algorithm, which we have named The Algorithm to Generate Description. Some words and

concepts will be used in the algorithm, so the list of their explanations is given below.

Group – specifies the group to which the question belongs.

QModType – indicates the affiliation of the question to the Multiple Groups. If it does not belong to any Multiple Group, its value is zero.

QText – contains preprocessed text of the question, which will be presented in the description of the organ.

QMultiple – if the set of questions from the same Multiple Group is repeated for several times, then we enumerate these sets. QMultiple indicates the set to which this question belongs.

The Algorithm to Generate Description for Organ contains the following basic processes (the logic scheme for algorithm is shown in Fig.2):

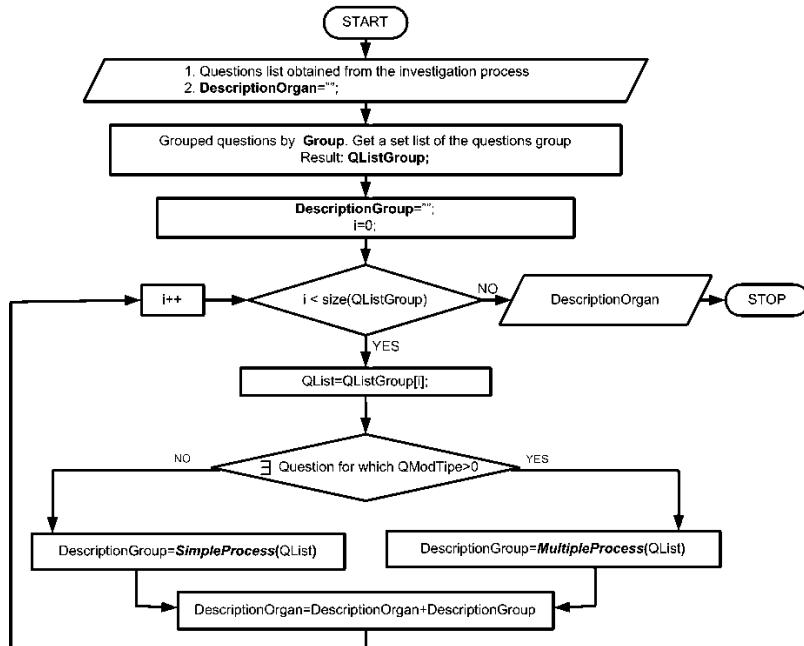


Figure 2. Logic scheme of Algorithm to Generate Description for Organ.

Step 1. Grouping the questions from the investigation process in *Group*. As a result we have a set of lists of grouped questions. We denote these lists by *QListGroup*.

Step 2. Generating the description for each *QListGroup* (in the logical scheme of the algorithm it is denoted by *DescriptionGroup*) when passing to the following steps:

Step 2.1. Determine if there are questions, which belong to a *Multiple Group* ($QModType > 0$). If no, then go to Step 2.2 (Fig.3), otherwise proceed with the Step 2.3 (Fig.4).

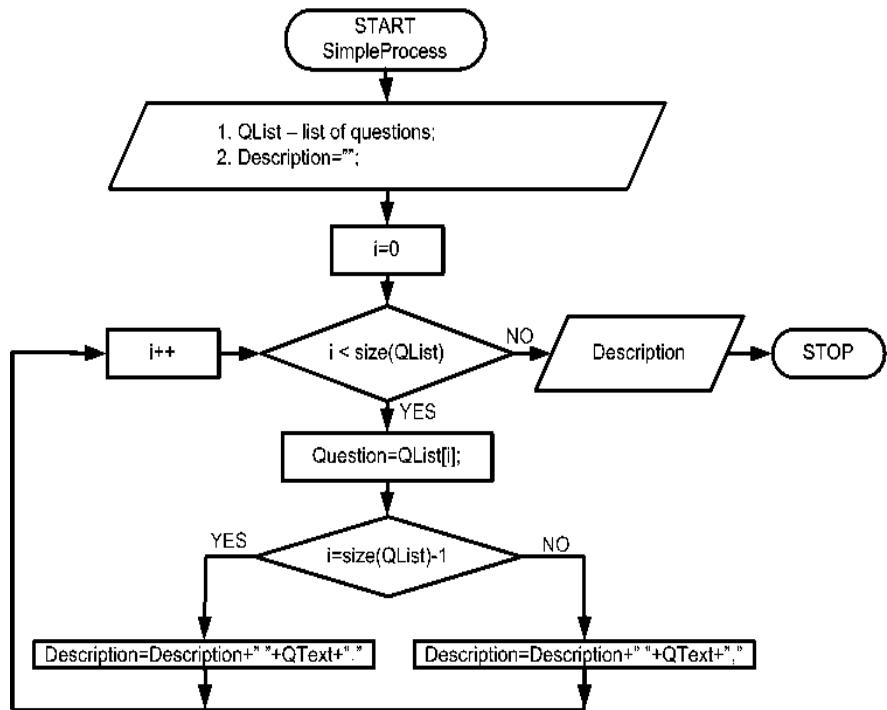


Figure 3. Logic scheme of Algorithm for processing the questions, which are not the part of Multiple Groups.

Step 2.2. Forming the description – *DescriptionGroup*, which is a

sentence obtained by joining the field *QText* for each of the questions from *QListGroup*. Determine:

- if the question is the last in the list of questions from group, then after *Qtext* the sign "point" will follow,
- otherwise, after *QText* the signs "comma" and "space" follow.

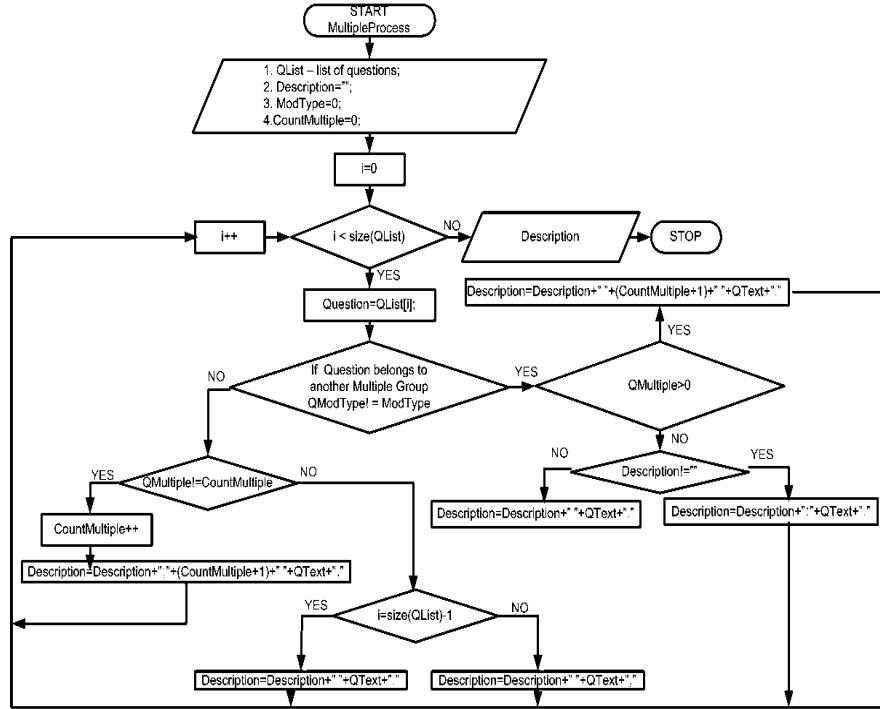


Figure 4. Logic scheme of Algorithm for processing the questions, which are the part of Multiple Groups.

Step 2.3. Forming *DescriptionGroup*, which is a sentence obtained by joining the field *QText* for each of the questions from *QListGroup*. This sentence is made as follows:

- Determine if the question is a part of *Multiple Groups* (*QModType* > 0), but its predecessor isn't (*QModType* = 0), then remove the last

two letters of *DescriptionGroup* (they are "space" and "comma"), and add "colon" and "space". This will highlight that farther the description of the previous question will follow.

For example, the question is $Q2 = \text{"Are the focal modifications immobile?"}$, it is part of Multiple Group ($QModType = 8$) and its predecessor is the question $Q1 = \text{"Are there focal modifications of the gallbladder contents?"}$, with $QModType = 0$. The affirmative answer ("Yes") to the question $Q1$ means that there are focal modifications of the gallbladder contents, and the Multiple questions of group $QModType = 8$ are the set of questions which describe the type of focal modifications. As a result we obtain "There are focal modifications of the gallbladder contents: immobile".

- b) if the set of questions from the same *Multiple Group* are repeated for several times in the investigation process ($QMultiple > 0$), we will enumerate these sets.
- c) if the question is the last in the list of questions for group, then after *Qtext* the sign "point" will follow,
- d) if the question is the last in the set of questions for *Multiple Group* and isn't the last in the list, then after *Qtext* the signs "colon" and "space" will follow,
- e) otherwise, after *QText* the signs "comma" and "space" will follow.

Step 3. Forming the organ description by joining the phrases *DescriptionGroup* obtained for each group (*QListGroup*).

For example for investigation process shown in Fig.1, the SonaRes system has generated the following description:

"Dimension is normal.

Shape is normal. Contour is clear, continuous, regular, with the image of homogeneous band.

The wall is with normal thickness.

There are focal modifications of the gallbladder contents: 1. immobile, the structures are ecogenic, the image has mass-like appearance, stable, homogeneous, localization is declive; 2. immobile, it forms acoustic effects, acoustic shadow, the structures are ecogenic, the im-

ages has mass-like appearance, stable, homogeneous, localization is de-clive.”

3.2 The conclusion for organ investigation

The important part of the ultrasound report is the conclusion obtained for each organ. In our case, if the doctor is agree with the conclusion inferred by the system, then this conclusion will be included in the report. With the help of algorithm for conclusion generation, the conclusion is generated from the list of pathologies obtained in the investigation process.

Some pathologies and anomalies can be described by a set of common characteristics of the organ (the same set of "questions-and-answers"). For example $P1 =$ "Vesicular biliary lithiasis. Floating calculus" and $P2 =$ "Vesicular biliary lithiasis. Mobile calculus", are characterized by the focal modifications of the gallbladder contents. To obtain more clear conclusion, in time of its generating, these pathologies must be arranged together. For example, let in the investigation process be deduced three pathologies: $P1 =$ "Vesicular biliary lithiasis. Floating calculus", $P2 =$ "Vesicular biliary lithiasis. Mobile calculus" and $P3 =$ "Benign tumor. Solitary adenomatous polyp of gallbladder". The first two pathologies are characterized by the focal modifications of the gallbladder contents and the last pathology is characterized by the modifications protrusive in lumen. Thereto, the pathologies and anomalies were grouped. In this case the conclusion should be the following:

*"Vesicular biliary lithiasis. Floating. Mobile calculus
Benign tumor. Solitary adenomatous polyp of gallbladder."*

The Algorithm to Generate Conclusion for organ contains the following basic processes:

Step 1. Grouping the pathologies and anomalies deduced from the investigation process in *Group*. As a result we have a set of lists of grouped pathologies. We denote these lists by *PListGroup*.

Step 2. Generating conclusions (*ConclusionGroup*) for each *PListGroup* as follows:

Step 2.1. Uniting the names of rules, separating them by the sign "point".

Step 2.2. Search the sentences which are repeated in conclusion, if exist - then eliminate. For example, the conclusion for the group "Vesicular biliary lithiasis" will be *ConclusionGroup* = "Vesicular biliary lithiasis. Floating calculus. Vesicular biliary lithiasis. Mobile calculus". The phrase "Vesicular biliary lithiasis", is repeated, we keep the first iteration, and the others are excluded. The final conclusion for this group will be: *ConclusionGroup* = "Vesicular biliary lithiasis. Floating calculus. Mobile calculus."

Step 3. Uniting consecutively the *ConclusionGroup*, separating by the sign "new line", as the result we get the conclusion for organ.

The logic schema of The Algorithm to Generate Conclusion is presented in Fig. 5.

3.3 Recommendation

The examination process may be finished with one of three results:

- conclusion;
- conclusion and recommendations for repeated investigation (the need for repeated ultrasound investigations over time);
- additional investigation (conclusion may be or not);

Under additional investigation we mean additional analysis – blood, urine, etc. No need for repeated ultrasound investigation. Family doctor gives the result on the basis of available tests.

3.4 Images

Presentation of data in this part of the report largely depends on technical possibilities. If there are opportunities for transmission of images from the ultrasound equipment to SonaRes system, then in investigation process the informative images of the area of ultrasound investigation are stored in the database. And in the module for report

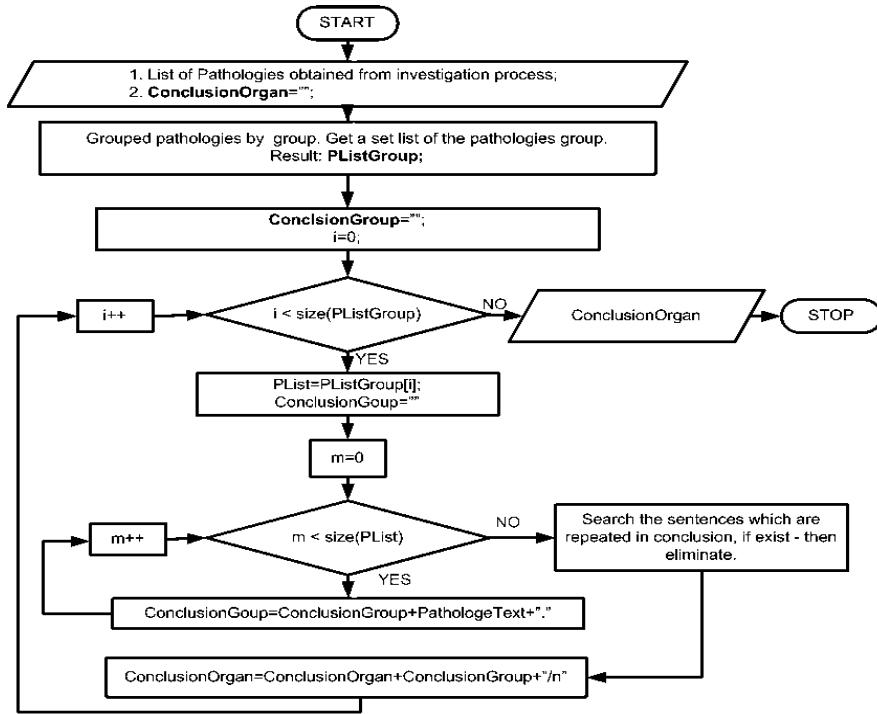


Figure 5. Logic schema of Algorithm to Generate Conclusion of Organ.

generation, the physician will select those images to be printed in the report.

4 The module for report generation

4.1 Main areas

The application consists of tree different areas: a menu section at the top, a report preview part to the right, a tool area to the left, as illustrated in Fig. 6. There are three main reasons for allowing the application to take up a lot of space, up to one full workstation monitor. First of all, the specialized applications may need a lot of space to fit

all necessary controls, so a large tool area is needed. Secondly, a report preview area is needed to convey to the user what is being created, while user interviews showed that covering the report presentation area with the tools is not an option. Finally, navigating through the application should require the user to use a minimum of "clicks", because clicks are perceived as time consuming. By allowing the interface to consume a lot of space, functionality may be made visible and accessible [3].

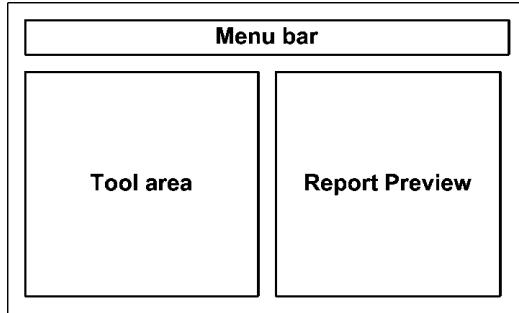


Figure 6. Application areas of generate report module.

In the section **Menu Bar**, we have established the following functions: Back, Save, Export PDF, Print. Back is the feedback functions. Save – save the report in database. Export PDF – export the report in PDF format. Print – print the report.

In the section *Report Preview*, the user can see how the report looks like. In this way the user at any time knows how the report is affected by any action.

In the section *Tools*, we have four areas that are specific to report: the conclusion, the description organ, recommendation and images. In each of these areas the data to be printed in the report can be viewed and modified.

In the areas of organ conclusion (Fig. 7) and description (Fig. 8) the list of conclusions and the list of descriptions for each organ can be viewed and modified. Conclusions and descriptions are displayed in fields of type "textarea", and for each field we have an FCKeditor, it

is an editor, with the help of which we can edit the text of conclusion and description. For each "textarea" we have two buttons:

- "Save" – when pressing this button the changes to the Tools section are presented in the Report Preview section.

- "Reset" button will undo all changes made in the "textarea" and show the organ conclusion or description, which was originally generated by the system.

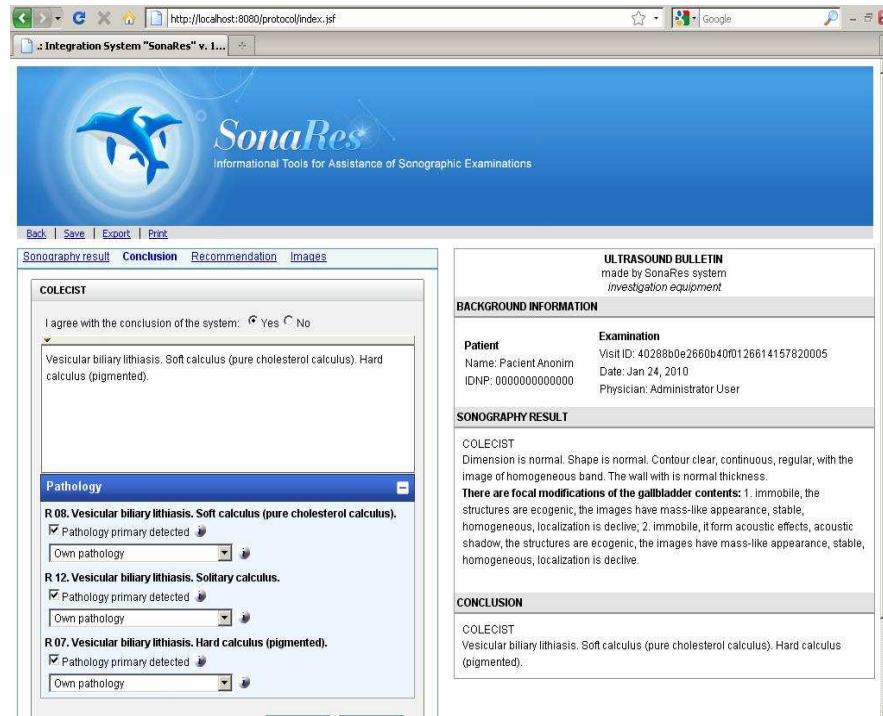


Figure 7. The screenshot of module for report generation: the area of Conclusion.

For cases, where the doctor does not agree with the system conclusion, we have one "radiobox", which indicates that "I do not agree with the conclusion of system". In this case the conclusion of sys-

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Figure 8. The screenshot of module for report generation: the area of Description.

tem is omitted and in the "textarea" the physician must describe this situation and indicate the cause.

Also when generating the report it is necessary to collect data which will be used to generate queries. For this purpose in the section "Conclusion" we also have a field: first detected pathology (in the sense that this pathology is found in this patient for the first time). So that such a query could be implemented, you need to include into protocol for each pathology the respective checkbox. That is, at the protocol level with the patient's words the user should indicate that the pathology was detected for the first time. If it is not for the first time (checkbox

is not activated), this fact is also installed with the words of the patient or on the basis of documents that the patient had brought about other investigations made not in this clinic.

In section Recommendation (Fig. 9), for each deduced pathology we have two "checkboxes". The first one indicates if for the detected pathology there is a need in the additional method of diagnostics. The second one indicates if for the detected pathology there is a need in the repeated examination.

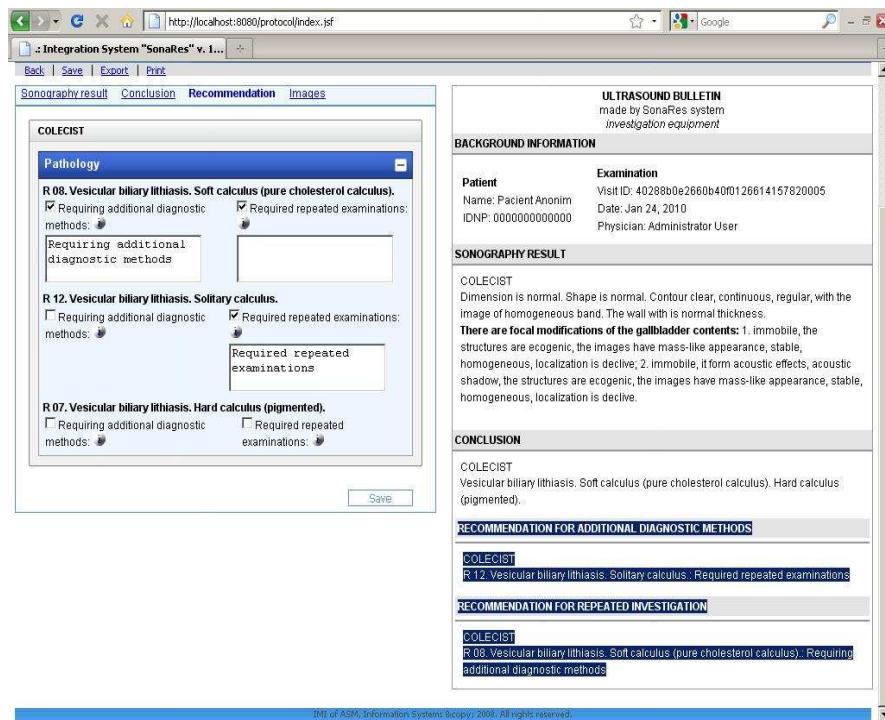


Figure 9. The screenshot of module for report generation: the area of Recommendation.

For each selected "checkbox" there is a field of type "textarea", in which the doctor will indicate what additional methods are required or

after what time it is necessary to repeat the examination.

In images section all the images obtained in the investigation process are given. Before each image we have a "checkbox" that allows to select or deselect the image. Selected images are printed in the report.

4.2 Implementation of report generation module

The module for report generation is a component part of SonaRes system (Fig. 10) and for printing the information in the report we use the information gathered from all parts of the system (these are the module of patient registration, the module of investigation, and data base).

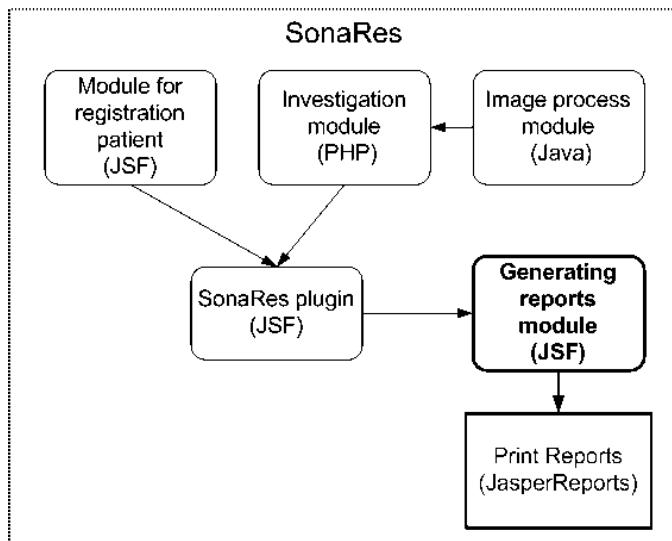


Figure 10. The structure of the SonaRes system.

To implement the module of report generation the following technologies were used: Java, JSF, JasperReports, Hibernate and a number of libraries that as FCKFaces [5], PrimeFaces [6].

5 Conclusion

An ultrasound examination process finishes with the report. The report itself contains all the information about one examination process: date, the data on patient, investigation result. Our goal was to implement a tool that will allow the data, generated in the report, be structured, be represented in language familiar for physicians and be easily edited by the user. With the help of modules for generating reports, the system generates this report and its date can be easily modified by the user.

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