Decision support system for breast cancer screening

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***Abstract*—Currently, decision support systems in radiation mammology focus on the detection and classification of neoplasms, despite the fact that the real work of a radiologist does not imply a diagnosing. Computer vision systems use a black box model and do not explain the results of work, which is unacceptable in medicine.**

The proposed hybrid approach, combining the work of computer vision subsystems and a problem solver based on graphodynamic sc-memory, can make a structured research report based on the detected anomalies and production output. This approach will reduce the time of the doctor-radiologist.

Also, for the first time, the decision support system of an X-ray technician is presented to improve the quality of breast styling. The system will improve the quality of the X-ray image and, accordingly, improve the evaluation of the study.

***Keywords*—Dicom, Ostis, Cad, Digital Mammography, Birads**

I. Introduction

Breast cancer is one of the most frequently diagnosed malignancies among women. So, in the United States in 2018, its share among all malignancies detected in women was about 30% [1]. Currently, mammographic screening remains the most effective method of early detection of breast cancer [2]. The goal of breast cancer screening is to reduce mortality by detecting a tumor before its clinical manifestation. The widespread use of this method makes it possible to detect breast neoplasms at an early stage, which improves the prognosis for the patient's recovery. However, the result in the population can be achieved under the conditions of ensuring the quality of diagnostics and sufficient coverage of the target group.

Due to the significant number of patients referred for screening mammography, the X-ray laboratory assistant and the doctor have limited time to perform and evaluate the study [3]. Therefore, the result of diagnostics is influenced by the time factor, the quality of equipment, the organization of the process and the qualification of staff.

Lack of time is a serious problem with a wide coverage of screening. To conduct the study, it is necessary to obtain 4 images: two projections for each laterality. In this case, the X-ray technician must make the correct placement of the breast on the deck, otherwise the image will be considered unsuitable for interpretation. On average, one study takes about 20 minutes. The doctor, in turn, must interpret 4 images and make a study report with a conclusion on the BiRads scale [4]. As a result, it takes at least 10 minutes. Thus, the study of one patient lasts at least 20 minutes.

Currently, X-ray screening of breast cancer in women is carried out using digital radiological mammographs. Usually, the technology of automatic exposure control is used, which allows you to exclude the possibility of incorrectly set exposure parameters of the image. The detectors of such devices allow you to shoot 16-bit images up to 5000*5000 and higher with a physical pixel size of the matrix from 0.04 mm. Such images take up about 50 MB in memory. However, for screening, as a rule, 4 images are produced: two projections of each laterality. Thus, the study takes about 200 MB in memory.

Images are not stored on a digital mammograph-the device is part of the radiological information system (RIS), which contains at least one picture archiving and communication system (PACS). In turn, RIS is part of the hospital information system (HIS), which contains demographic and clinical information about the patient, which can be used by a doctor to compile a report.

The doctor's workplace is also included in the RIS and consists, usually, of a research viewer and a gateway to HIS.

The screening process can be organized on the basis of a hospital or with the help of mobile mammographic complexes. When using the mobile option, the doctor can evaluate the studies only when they are moved to PACS, which can happen only after a few days.

During screening studies, the obtaining and interpretation of images are almost always separated in time. In this case, the X-ray laboratory technician may make a mistake and make an incorrect set-up or perform a study with incorrect exposure parameters, which will make the study unsuitable for further interpretation.

The qualification of an X-ray technician is extremely important: in case of incorrect breast placement for the study, the images cannot be evaluated. But the most important qualification is that of a radiologist-mammologist. Due to the insignificant dynamic range of tissue densities and as a consequence of the low image contrast, the detection of pathology requires considerable experience from a doctor. The complexity of image interpretation generates hypo and hyperdiagnostics, that are, errors of the first and second kind. Often, it is possible to distinguish pathologies only with a retrospective comparison of images. Since the 2010s, the workplaces of doctors of some manufacturers have been equipped with a computer diagnostics system (CAD), which allows determining neoplasms on images. However, their effectiveness is quite low due to the large number of false positives cases [5].

Thus, the following approaches to improving the quality of breast cancer screening can be identified:

- Automatic assessment of the quality of breast placement at the laboratory assistant's workplace;

- Prediction of possible pathology at the laboratory assistant's workplace during screening based on mobile complexes;
- Automated compilation of a structured research report at the doctor's workplace.

II. Suggested system architecture

To automatically assess the quality of breast styling at the laboratory assistant's workplace, it is necessary to solve the following tasks:

- Determine the location of the breast nipple outline;
- Determine the outlines of the chest muscle for the MLO projection;
- Determine the type of X-ray density of the breast;
- Develop an algorithm for determining the quality of laying on the scale "Unsatisfactory-Good-Excellent"

The main limiting factor in the development of this subsystem is the speed of operation. The laying assessment procedure is integrated into the workflow of obtaining an image on an X-ray machine. And the evaluation stage should not exceed 20 seconds.

The subsystem should also have the ability to integrate any mammographic device into the diagnostic process. It is worth noting that the component must be fault-tolerant, and its failure should not affect other parts of the system.

Thus, the subsystem consists of a server and a client part and interacts via the grpc protocol. Dicom storage is used as a container for images. The subsystem architecture is shown in Fig. 1.

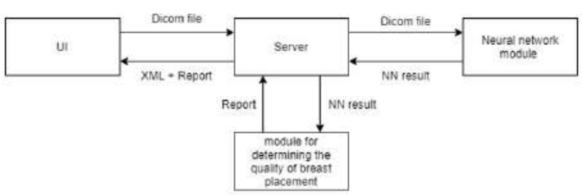

Figure 1. Architecture of the subsystem for assessing the quality of breast placement.

The purpose of the system for predicting possible pathology at the laboratory assistant's workplace is to early identify patients who may need additional research. Thus, the system can offer the laboratory assistant to additionally perform mammography with tomosynthesis, and a structured report on automatically found artifacts can also be included in the results of the study.

The purpose of the system of automated compilation of a structured research report at the doctor's workplace is to reduce the time for manual compilation of the report and the translation of the report into a machine-readable form.

A system capable of automated creation of a mammographic examination protocol must match the following criteria:

- The entire study should be provided to the system for input: several projections (images) for each laterality (left, right), their metadata, patient metadata (age, information about the hormonal background).
- Communication with the system should be carried out in a language based on BiRads.
- The system must have knowledge about radiation diagnostics in mammology: statistics on the occurrence of pathologies and their symptoms, the compatibility of symptoms, etc.

The study (4 images and a study report) is supplied to the input of the handler, which sends images to the recognition modules of diagnostic criteria. Each criterion (artifact) recognizes a separate recognition module. Based on the found criteria, the handler forms a request to the knowledge processing machine for verifying and supplementing search results. The knowledge processing machine for differential diagnostics can request additional data (from the user or another data source). The response of the knowledge processing machine is translated by the research handler into a machine - and human-readable report in a subject-dependent language based on BiRads.

The schematic diagram of this system is shown in Fig. 2.

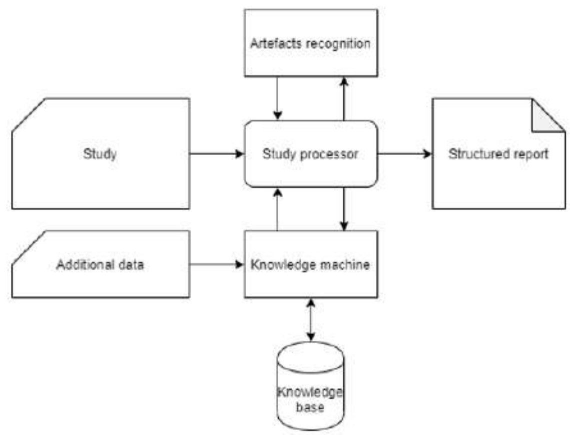

Figure 2. Schematic diagram of the decision support system of a radiologist.

III. Data preparation

The main limiting factor in the development of this subsystem is the insufficient amount of training data. To create a report, you need to mark up images for classification or segmentation by 21 criteria. Doctors should mark up images using professional medical monitors. In this regard, a markup language based on the Birds lexicon was developed. The markup language was built into the Dicom viewer MedXView and all the markup metadata was stored in Dicom storage. Currently, 800 studies have been collected with an acceptable quality of breast styling, all of them were marked up by doctors. At the same time, various pathologies were found only in 84 studies (10.5%). Thus, the initial data is sufficient only for the full implementation of the breast styling quality assessment system at the laboratory assistant's workplace.

IV. Implementation of the system of automatic assessment of the quality of breast placement

The tasks of the subsystem for automatic assessment of the quality of stacking are to determine the location of the outline of the breast nipple, to determine the outlines of the pectoral muscle for the MLO projection, to determine the type of X-ray density of the breast, to determine the quality of styling on the scale "Unsatisfactory-Good-Excellent".

To implement this task, 2 modules were developed. The module that controls the launch of neural networks and the processing of the results obtained. And the module that determines the quality of the placement.

During development, we used grpc technology to interact with the client. The subsystem of automatic assessment of stacking is a service.

The definition of the laying quality varies depending on the projections. At the moment, two algorithms have been implemented for CC and MLO projections. After the image is processed by the neural network and the coordinates of the nipple and muscle are received (for the MLO projection), the stacking assessment algorithm is started.

For the CC projection, the stacking is considered excellent if the nipple is located close to the center of the image vertically.

For the MLO projection, the styling is considered excellent if the nipple and the lower border of the muscle are on the same line or very close.

The neural network for determining the boundaries of the nipple correctly finds it in 84% of cases. The neural network, by determining the density, gives the correct result in 82% of cases. The neural network for determining the boundaries of the muscle as a result gives the correct result in 96% of cases.

V. Implementation of the System of Automated Compilation of a Structured Report

Taking into account the fact that there is not enough training data on the images of the report compilation system to implement the subsystem for recognizing diagnostic criteria, the system was partially implemented.

So, the input-output subsystem and the decision-making subsystem were implemented.

The decision-making subsystem consists of a knowledge processing machine and a knowledge base.

The tasks of the decision-making subsystem are the description and use of medical knowledge to generate forecasts of nosological forms in patients, verification of the output of each of the recognition modules, selection of a conclusion on the BiRads scale, conclusion of a hypothesis about the disease.

The task of the knowledge base is to formalize knowledge in the field of mammology. Medicine is a complex subject area and its knowledge model is difficult to describe in the form of a relational model. OSTIS technology is used to represent the model of knowledge about mammology [6].

The knowledge base consists of subject and utility ontologies. The subject ontology describes the BiRads language and the hierarchical structure of artifacts (diagnostic criteria) and diseases. In turn, the utility one is the basic ontology of IMS OSTIS.

The template for describing the patient's study was developed using a graphical representation of the SC-code. The description of the study consists of different parts:

- from the part of the patient's passport data,
- from the part of the image metadata description
- from the part describing all the diagnostic criteria found by the artifact recognition subsystem.

The passport data of the patient at the moment consists of the nodes of the hormonal status of the patient and his age. In the future, it will be possible to add information about previous studies and about the studies of relatives, which will affect the calculation of the probability of a particular disease.

The description of the image metadata consists of information about the projection, width and height, laterality, and so on. This information is taken from Dicom files.

Artifacts are divided into laterality artifacts and artifacts that have a specific location in the image. When processing an image, the neural network finds all the artifacts and their attributes and uses tags and values to describe them. The information is then translated into a graph view. Artifacts have properties that are also described in the graph structure. For example, the formation has margins, shape, density, size, distance from the nipple. For example, the total breast density can be considered an artifact of laterality.

Many nosological forms have been described. They are divided into normal, benign, suspicious, and potentially suspicious. Each nosological form has a probability distribution of occurrence by age. The nosological form has features, they are also artifacts, which are formalized according to the same template as the study.

The probabilities of occurrence of the nosological form are very rarely described in the literature. Therefore, we had to use the real experience of doctors - to get several invaluable consultations from specialists in their field. Also from the literature [7], descriptions of nosological forms and probabilities of occurrence of each artifact and its properties in this form were taken.

The domain ontology uses static and dynamic ontologies. We have filled static ontologies with immutable data about diseases, artifacts and their properties. The dynamic ones are filled in during the work and form a description of the patient's study based on DICOM.

The problem solver is a graphodynamic sc-machine (memory uses a semantic network as a model of knowledge representation), consisting of two parts:

- graphodynamic sc-memory;
- sc-operations systems.

The system of operations is agent-oriented and is a set of sc-operations, the condition for initiating which is the appearance of a certain structure in the system's memory. In this case, the operations interact with each other through the system memory by generating constructs that are the initiation conditions for another operation. With this approach, it becomes possible to ensure the flexibility and extensibility of the solver by adding and/or removing a certain set of operations from its composition.

There are currently seven agents:

- probability counting agent;
- an agent who creates a report on the patient's passport data;
- the agent who creates the research report;
- an agent that generates a general report;
- agent for generating the study structure
- report verification agent
- agent for verifying the size of the formation

As a result of the agents work, a list of nosological forms and their probabilities of existence in this study is obtained, sorted in descending order.

A BiRads-based language is also used to transfer information between subsystems and process research. The markup language is represented in both SC-code and XML.

The decision-making subsystem receives an XML file with the result of the recognition modules. After that, a graph structure is generated in semantic memory, the formations are validated and the modules are checked. Patient reports, studies are created and the probabilities of the presence of nosological forms are calculated. A structured report is created. In this case, the doctor can edit the created report and save it to PACS.

VI. Conclusion

Currently, decision support systems in radiation mammology focus on the detection and classification of neoplasms, despite the fact that the real work of a radiologist does not imply a diagnosing. Computer vision systems use a black box model

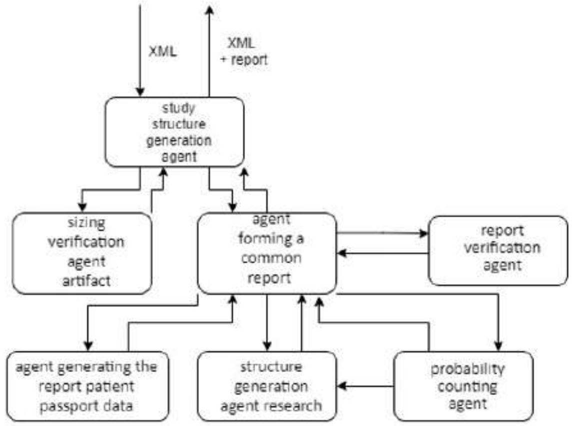

Figure 3. Interaction of agents of the structured report generation subsystem.

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The proposed hybrid approach, combining the work of computer vision subsystems and a problem solver based on graphodynamic sc-memory, can make a structured research report based on the detected anomalies and production output. This approach will reduce the time of the doctor-radiologist.

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Система поддержки принятия решений при проведении скрининга рака молочной железы

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В настоящее время системы поддержки принятия решений в лучевой маммологии концентрируют внимания на выявлении и классификации опухолей несмотря на то, что реальная работа врача-рентгенолога не подразумевает постановку диагноза. Системы компьютерного зрения используют модель черного ящика и не объясняют результаты работы, что неприемлимо в медицине.

Предложенный гибридный подход, совмещающий работы подсистем компьютерного зрения и решателя задач на основе графодинамической sc-памяти может составлять структурированный отчет исследования на основе обнаруженных аномалий и продукционного вывода. Такой подход позволит сократить время врача-диагностика. Так же впервые представлена система поддержки принятия решений рентген-лаборанта для улучшения качества укладки молочной железы. Система позволит улучшить качество рентгеновского изображения и соответственно улучшить оценку исследования.

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