Graphical data processing in the Clinical Decision Making System for the Respiratory Diseases Diagnosis using ML methods

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Abstract. This article considers the basic algorithm of graphic data extraction used in the developed system of clinical decision-making in diagnosis of respiratory diseases, methods for processing files in JPEG and DICOM formats, visualizing and preprocessing images as well as constructing neural network models based on a convolutional neural network that provide detection symptoms of pneumonia in patients based on radiographs. Data extraction and processing are performed in the "Python" programming language using additional libraries: "pydicom" for processing DICOM files, "Pillow" for visualization, "Keras" for building a convolutional neural network model. The relevance of the task is due to the large volumes of graphical data supplied to the input of the CDSS and necessary for its effective functioning. The novelty of this development lies in the application of a set of existing and development of new algorithms for extracting and processing graphic information.

Keywords: Clinical decision support system; Data processing; Processing of graphic information, CNN, Computer vision

1. Introduction
Active penetration of information technologies into medicine and healthcare has stimulated development of software systems with the main goal of improving quality of medical services by introducing modern intelligent technologies and machine learning technologies in the process of interaction between medical personnel and patients. One of the most effective means to achieve this goal is by using clinical decision support systems (CDSS). CDSS are systems designed to help doctors and other medical professionals in working with tasks related to clinical decision-making, focused on processing and managing information to formulate recommendations for patient treatment based on available data [1]. The use of CDSS ensures increased efficiency of diagnosis and treatment of patients, and also reduces the burden on the doctor when processing information.

In [2], the authors describe the development of the clinical decision support system architecture in the diagnosis of respiratory diseases. This system presupposes the presence of such functions as analysis of patient data in the form of text, graphic and sound information, formulation of a presumptive diagnosis based on the analysis and identified patterns as well as formation and issuance of medical recommendations to improve the effectiveness of patient treatment [3].
This article is devoted to the consideration, description and implementation of a basic algorithm used in:
- converting data from DICOM format to JPEG format;
- uploading images (results of X-ray examinations of patients) in the form of JPEG files;
- preprocessing of uploaded images;
- use of machine learning algorithms to predict the presence of a disease (pneumonia) in a patient.

The implemented algorithm is a component of the graphic data recognition unit of the developed clinical decision support system in the diagnosis of respiratory diseases.

2. State of art
Graphic information in medicine, as a rule, is represented by three types of images:
- radiographs;
- images of computed tomography;
- pictures of magnetic resonance imaging.

The most common type of medical imaging in the area under consideration (i.e., pulmonology) is a chest X-ray. To obtain images, X-ray devices allowing to project the structure of a person's internal organs onto a special film or paper using X-rays are used.

Chest X-rays are useful for diagnostics of such conditions as
- pneumonia;
- pneumothorax;
- interstitial lung disease;
- heart failure;
- bone fractures;
- hernia of the esophageal opening of the diaphragm [4].

Today, there are many solutions on the market that implement the functionality of medical image recognition.

For example, the Imsight Technology company, which produces computed tomographs, at the end of May 2020 presented a development in the field of artificial intelligence for CT diagnostics of lung diseases under the name of Imsight CT Analysis System [5], which establishes a preliminary diagnosis in 10 seconds.

The CheXNext algorithm [6], created at Stanford, examines a chest image and checks it for 14 pathologies. The results show that the algorithm detects 10 out of 14 pathologies faster and better than experienced radiologists.

One of the main Russian developments is the "Botkin.AI" company "Intellodzhik" [7]. Botkin.AI is used to diagnose and assess disease risks using artificial intelligence technologies and is a platform for analyzing medical images. The platform allows for analysis of the patient's chest based on computed tomography images, mammography screening, detection of lung cancer as well as pneumonia caused by Covid-19.

Another Russian development was carried out by the Care Mentor AI company [8], and is a neural network that is used to describe X-ray images. The technology allows you to get a description and a preliminary diagnosis within 3 seconds after taking a picture. This product has also been enhanced with the ability to detect Covid-19. The diagnostic accuracy is about 84%.

Nevertheless, the presented developments are independent projects that process exclusively graphic medical data and obtain results only on their basis, while the CDSS described in this article involves the complex use of information about the patient, i.e., text, graphic, or sound, which will significantly improve the efficiency of the system in diagnosing patients.

3. Main problems in recognition in CDSS
The main problem of creating a module for recognizing graphic data of the system being developed is the heterogeneity of the initial information, which consists of the following factors:

- radiographs can be performed on different X-ray machines with different settings and environmental conditions;
- the projections of the lungs captured in the image may be displaced relative to the center of the image due to insufficient accuracy of the device, as well as the physiological characteristics of patients;
- X-ray images can contain significantly noisy frames and frames of low quality;
- it is difficult to obtain a uniform and sufficient number of images from patients with various diseases, since the incidence of diseases can vary significantly.

It should also be noted that radiographs created with medical equipment are usually stored in DICOM format. DICOM (Digital Imaging and Communications in Medicine) is a medical industry standard for the creation, storage, transmission and visualization of digital medical images and documents of examined patients [9]. DICOM is based on the Open System Interconnection (OSI) standard developed by the International Organization for Standardization (ISO). This standard is supported by major medical device and medical software manufacturers.

4. Proposed solution

The problem of processing X-ray images in the developed DSSP may be approached by solving the problem of pattern recognition or by the task of training with a teacher.

This work solves the problem of binary classification (dividing patients into two classes - with and without detected pneumonia). The Chest X-Ray Images (Pneumonia) of the Kaggle platform [10] are used as a dataset for training and testing. The sizes of the data sets for training, validation and test samples are shown in Figure 1.

![Figure 1. Number of images in the "Chest X-Ray" dataset](image)

The current dataset is JPEG images that do not require additional conversion. If files in DICOM format are received at the block input, additional conversion is required using the "pydicom" library [11]. DICOM and JPEG file formats are automatically recognized by reading their own extensions.

Images are displayed using the Python Imaging Library (PIL) [12]. Examples of snapshots are shown in Figure 2.
As a framework for building a neural network, the "Keras" is used [13], since it is a fairly fast and efficient add-on over the deep learning libraries "TensorFlow", "Theano" and "Deeplearning4j".

To improve the generalizing ability of the future neural network, augmentation is performed as follows:

- horizontal flip of images is applied (horizontal_flip);
- the range of image pixel shift is set to 0.2 (shear_range);
- the range of random selection of image scaling (zoom_range) is set.

A convolutional neural network (CNN) is utilized as the architecture of a neural network, since networks of this type are known by their high ability to recognize patterns in images. In a convolutional neural network, the outputs of the intermediate layers form a matrix (image) or a set of matrices (multiple image layers). So, for example, three image layers (R-, G-, B-image channels) can be fed to the input of a convolutional neural network. The main types of layers in a convolutional neural network are convolutional layers, pooling layers and fully-connected layers [14].

The architecture of the created neural network is shown in Figure 3. The input of the neural network receives an image of 128x128 pixels in size. Next, the image goes into a bunch of Conv2D and MaxPooling2D layers.

Conv2D is a convolutional layer that applies convolution to input images and consists of customizable and trainable filters. The convolution kernel weights are trainable parameters. Another training weight is used as a constant shift.

MaxPooling2D is referred to as a sample-based sampling layer, which aims to downsample the input layer based on the maximum value of the subsampling window.

The Flatten layer transforms the resulting matrix into a one-dimensional vector, after which the final transformations are performed using fully connected layers (Dense).

The created implementation of the convolutional neural network is configured as follows:

- Algorithm for optimization of gradient descent - Adam;
- Loss function – Binary cross entropy;
- Quality metric – Accuracy.

The best results obtained after training the neural network and testing on test data:

- the accuracy value on the training set – 0.84;
- the accuracy value on the test set – 0.80;
The accuracy values on the training and test samples differ insignificantly from each other, while the value on the test sample is consistently lower than the value on the training sample, whereupon it may be concluded that the resulting model is not overfitted and has a sufficiently high efficiency of X-ray pattern classification.

Further tasks to improve the quality of the model consist in increasing the number of images, expanding the library of images for diseases other than pneumonia, which will make it possible to move to the task of multiclass classification, and augmenting the capabilities of the DSS. The capabilities of the developed module for processing graphic information can also be expanded by building additional models for detecting diseases by evaluating images of computed and magnetic resonance imaging. The use of pre-trained neural network mechanisms such as ResNet, ImageNet is allowed.

The implementation of the developed algorithm for processing graphic information is located in the repository [15].

5. Conclusions
The article considers the algorithm for processing graphic information obtained from radiographs of patients with and without pneumonia, developed for a clinical decision support system in order to create a classifier that detects pneumonia in a patient:
6. The algorithm has been developed that allows processing JPEG graphic files and medical standard DICOM files;
   • functional for previewing the received radiographs has been developed;
   • the architecture of a convolutional neural network has been developed, which most effectively
     performs the task of classifying patients;
   • an assessment of the trained classifier was carried out, as a result of which the best results of
     the accuracy metric on the training set were 0.84, while on the test set they were 0.80;
   • directions for further improving the quality of the classifier are highlighted.

   The developed models and algorithms will make it possible to classify the presence or absence of
   pneumonia based on the obtained X-ray of the patient, then combine the information with the data
   extracted from the textual description of the symptoms and the tabular result of the patient's analyzes,
   and ensure its transfer to the decision-making module, whose functionality, in turn, will allow you to
   establish the most likely diagnosis for each patient.

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