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[1]**V. M. Sineglazov,**
[2]**Y. V. Kharchuk**

INTELLECTUAL SYSTEM OF PREPARATION OF IMAGES FROM COMPUTER TOMOGRAPHS

Aviation Computer-Integrated Complexes Department, Faculty of Air Navigation Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine
E-mails: [1]svm@nau.edu.ua ORCID 0000-0002-3297-9060, [2]yari.future@icloud.com

Abstract—*Artificial neural networks can be trained on useful signals of the source data, but can not be taught on noisy data, so it is usually performed noise reduction or error compensation. This paper implements a noise reduction model based on artificial neural networks to suppress high-noise components, which is important for optimizing pre-filtering methods. The process of cleaning computers' tomography scans in medical examinations of patients with tuberculosis is considered as an given problem in which the suppression of noise present in the image is required.. In order to reduce the level of radiation due to it is quite harmful to human. the power of the radiation is reduced. As a result, the ratio of the useful signal to noise is reduced, which causes noise, which contaminates the image and complicates its processing. Additional shadows appears on the image that no objects exist, which can provide false diagnosis. An algorithm for structural-parametric synthesis of convolutional neural networks used in image noise suppression has been developed. Computer tomograms of tuberculosis patients provided by the Research Institute of Pulmonology and Tuberculosis of the National Academy of Medical Sciences of Ukraine were used as a training sample.*

Index Terms—Intelligent system; tuberculois; X-rays; convolutional neural networks; computer tomography; CycleGAN; neural networks; UNET; ResFCN; MobileNetV2.

I. INTRODUCTION

In late December 2019, Stanford University published the results of a study according to which the computing power of artificial intelligence is more than seven years ahead of Moore's Law. This law says that CPU speed doubles every 18 months, so developers can expect to double the performance of applications in these terms are for the same cost of equipment. But a report by a team of researchers from Stanford University, prepared in collaboration with McKinsey & Company, Google, PwC, OpenAI, Genpact and AI21Labs, showed that the computing power of intelligent system (AI) is growing faster than the power of traditional processors. The turning point, when the speed of development of artificial intelligence began to precede Moore's Law, was 2012 [1].

The first research in the field of AI, which started in the 50s of the last century, was aimed at solving problems and developing systems of symbolic calculations. In the 1960s, this trend attracted the interest of the US Department of Defense: the US military began teaching computers to mimic human mental activity. For example, the US Department of Defense's Advanced Research Projects Office (DARPA) carried out several virtual street map projects in the 1970s, and DARPA managed to create intelligent personal assistants in 2003, long before Siri, Alexa and Alexa Cortana. These works became the basis for the principles of automation and formal logic of reasoning used in modern computers, in particular, in decision support systems and intelligent search engines designed to complement and increase human capabilities.[2,8]

Today, Ukraine is one of the global sources of post-Silicon AI innovation and related technologies. We are receiving the largest number of international grants for AI development, winning competitions and receiving significant investments.

Ukraine is one of the leading suppliers of AI technologies in Eastern Europe and the world. Ukraine's IT is the third largest industry, the third largest export sector now. Possibilities of artificial intelligence:

- increase business productivity through widespread automation of basic business processes (including the use of robots and autonomous transport systems);
- increasing the demand for products and services of companies through their personalization and individual approach to each client. This will help the use of AI-assistants and analytical programs;
- automation of audience filtering processes online, sampling of potential customers;
- automation of processes of registration of orders, orders and sales;

- security control and implementation of a smart authentication system [3], [4], [7], [9].

II. Intelligent Systems of Medical Diagnostics as an Improvement Accuracy of Diagnosis

Health information systems are currently being actively developed. One of the promising areas of the current stage of health informatization is the development of intelligent medical diagnostic systems (IMS), which provide support for decision-making by physicians. This is primarily due to the lack of experience of doctors, rapid development of medicine and lack of time resources for training and experience of staff, resulting in the use of duplicate research and wasted expensive and unnecessary treatments [5].

The intellectual element of IMDS is the neural network (NN), which is used to process ultrasound, computer tomography (CT), magnetic resonance imaging (MRI) and support decision-making regarding the final diagnosis [22], [23].

When solving applied problems in order to increase accuracy and reduce complexity, the task of finding the optimal network topology and, accordingly, structural (determining the number of hidden layers and neurons in them, interneuronal connections of individual NN) and parametric (weighting) optimization. One of the leading trends in modern computer science has been the development of hybrid NN (consisting of various structures united in the interests of achieving goals) based on deep learning, which allows to solve complex problems (especially medical image processing), which can not be solved based on individual methods or technologies. To date, the most effective means of image processing are convolutional neural networks (CNN). The convolutional neural network is built on the basis of the convolution operation, which allows to teach CNN on separate parts of the image, iteratively increasing the local learning area of a single convolution nucleus [24], [25], [17].

III. Problem Statement

Solving the problem of determining the degree of activity of the inflammatory process of tuberculosis by found active foci on CT images of patients requires the construction of a comprehensive algorithm with additional processing (cleaning and selection of informative scans) and post-processing (cleaning and refining masks) data.

The task of image restoration is, as a rule, incorrect (very unstable) and to solve it it is necessary to use modern, stable methods. The task of image restoration task is quite simple and clear. At the same time, solving this problem requires the use of quite diverse and complex tools, including mathematical modeling, statistical estimation theory, Fourier transform, optimization methods, numerical methods of linear algebra and others. Now let's move on to a more formal and scientific description these processes of distortion and recovery. We will consider only halftone black and white images under the assumption that to process a full color image it is enough to repeat all the necessary steps for each of the RGB color channels.

The image is often distorted due to the imperfection of optical devices, defocusing images, due to the influence of the environment between the object and the device for a number of other reasons [21], [20].

The main task is the semantic segmentation of CT images into two classes: tuberculoma and background.

IV. Computer Tomograph and Noise Types

Computed tomography has become one of the major breakthroughs in diagnostic radiology.

The first clinical computed tomography was created by G. N. Hounss field for head examination and installed in 1971 at Atkinsonn Morley Hospital in Wimbledon, England. The first body tomograph was installed in 1974, and by the end of the 1970s the technical evolution of CT was largely completed.

Computed tomography is a method of X-ray tomography in which a beam of X-rays passes through a thin layer of the patient's body in different directions. Parallel collimation is used to form a beam in the form of a thin fan that determines the thickness of the layer being scanned. Attenuated radiation intensity at the output of the patient's body is measured by detectors. Mathematical reconstruction of images (inverse Radon transformation) allows you to calculate the local attenuation of radiation at each point of the cut. These local attenuation coefficients are converted to CT numbers and finally converted to grayscale, which are displayed on the screen, forming an image. The signals recorded by the detectors during the scan are pre-processed to compensate for the inhomogeneities of the detector system and to correct artifacts caused by the increased stiffness of the radiation inside the examined body. The data obtained after different steps of correction and conversion of the signal intensity of the X-ray attenuation value are called the initial CT data. The array of initial data on tomographs of the 3rd and 4th generations consists of radiation attenuation profiles from 500–2300 projections for each rotation of the X-ray tube by 360°. Each projection, in turn, is 500-900 values of attenuation of radiation [10].

Reconstructing an image from an original data array creates an image data array.

A. Gaussian noise

The main sources of Gaussian noise in digital images occur during its acquisition, for example, sensor noise caused by poor lighting and / or high temperature, and / or transmission, such as electronic circuit noise. The standard model of this noise is additive, independent in each pixel.

B. Noise of salt and pepper

Common "thick tail" or "impulsive" noise is sometimes called salt and pepper noise or spike noise. An image that contains salt and pepper noise will have dark pixels in the light areas and bright pixels in the dark areas.

C. Poisson noise

Poisson noise or fractional noise is a type of electronic noise that occurs when a finite number of energy-carrying particles, such as electrons in an electronic circuit or photons in an optical device, are small enough to cause statistical fluctuations in a measurement.

D. Fractional noise

The predominant noise in the lighter parts of the image from the image sensor is usually the cause of statistical quantum fluctuations, ie changes in the number of photons perceived at a given level of influence. This noise is known as fractional photon noise.

E. Blind noise

The image is often distorted due to the imperfection of optical devices, defocusing images, due to the influence of the environment between the object and the device for a number of other reasons [11].

V. High-performance Convolutional Neural Networks

The convolutional neural network is a special architecture of the artificial neural network created for high-efficient recognition operations . In case of MRI image of liver fibrosis it's necessary to process the texture of image.

There are some principal types of CNNs used for image classification: ResNet, CycleGAN, UNet, Mask RCNN.

ResNet is an abbreviation for Residual Network. The ResNet model has fewer filters and less complexity than VGG networks. ResNet converges faster than its simple analog, while deeper ResNet achieves better learning results than an non-deep network.[12]

CycleGAN is a type of generative adversarial network used to carry image style. CycleGAN can be trained to convert images from one domain (e.g. Fortnite) to another, such as PUBG.

UNet is considered one of the standard CNN architectures for image segmentation tasks, when it is necessary not only to determine the entire class of an image, but also to segment its areas by class, i.e. create a mask. The network architecture is a sequence of layers that first reduce the spatial resolution of the image, and then increase it by first combining it with the image data and passing through other layers of the convolution. Architecture the convolution network UNet can be used not only for segmentation, but also for detecting objects in images.

Mask RCNN – a network with this architecture allows you to highlight the contours (masks) of different objects in photographs, even if there are several such objects, they have different sizes and partially overlap. The network is also capable of recognizing the poses of people in the image. Mask RCNN develops the Faster RCNN architecture by adding another branch that predicts the position of the mask covering the found object, and thus solves the instance segmentation problem [13], [14].

Since in this work it is necessary to classify the texture of liver tissue, high demands are placed on the accuracy of solving the classification problem [6].

The better results are given by ResNet, which is based on the so-called residual block (Fig. 1), with a shortcut connection through which data passes without changes. The Res block is a series of convolutional layers with activations that convert the input signal x to $F(x)$. A shortcut join is an identity transformation $x \to x$. The architecture of the ResNet represented on Fig. 2.

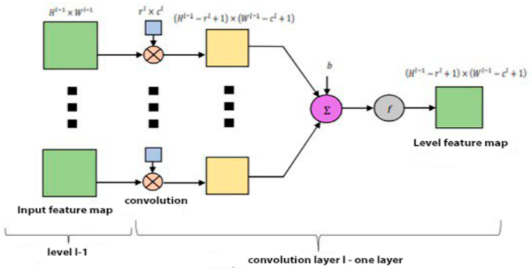

Fig.1. The residual block of the ResNet architecture

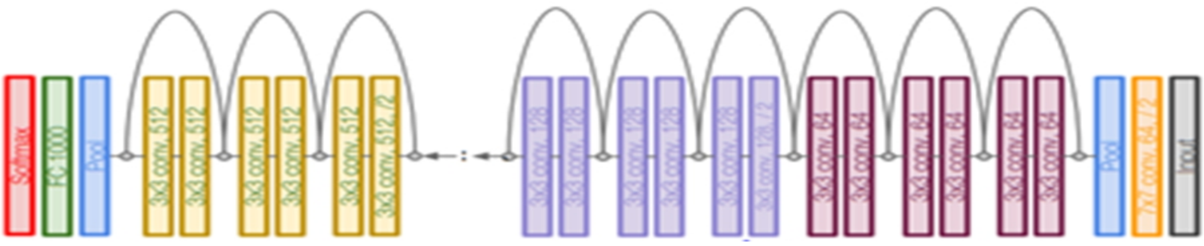

Fig. 2. Architecture of the ResNet

Using the ResNet architecture, it was possible to train a neural network with a depth of 18 layers (against the three-layer network used in the initial stages of work) with achieving acceptable recognition results simultaneously for 10 classes (five are sufficient for recognizing liver fibrosis) with a small number of images in the training set.

To make the final decision on the class of the analyzed image, the SoftMax layer was used with the number of outputs corresponding to the number of classes considered. The resultant class was the one that corresponded to the output of the SNA with the maximum response. One of the possible ways to take into account possible unknown classes and empty background images is to introduce a response threshold on the output layer of the SNA and treat the case "maximum response <threshold" as "not recognized" [15], [16].

A feature of the ResNet architecture is that the convolutional layers have 3x3 filters, as well as the fact that a quick connection is added to the network, which turns the network into its residual version.

The main point of this approach is to add paths to bypass groups of neural network layers, forming a residual block.

Deep learning-based algorithms provide a powerful framework for automatic feature generation and image classification using MRI on liver fibrosis. Such algorithms eliminate the need for manual segmentation and feature extraction from the images. However, they demand the use of a large training dataset.

Based on transfer learning being a variant of the typical deep learning-based algorithms – in that the neural network is pre-trained by a very large number of training datasets worldwide using weakly or even irrelevant image sources, – we hypothesized that the pre-trained deep learning neural network in transfer learning approach can accurately stage liver fibrosis in a fully automated manner.

VI. Problem Solution

The ensemble of deep convolution neural networks of medium size (~ 30–40 million scales), focused on medical data, is proposed to carry out the main segmentation processing of scans to maximize accuracy. Most modern approaches do not have an end-to-end approach in the diagnosis of the disease, so this paper developed a new methodology for detecting tuberculosis and determining the degree of tuberculosis activity by solving the following tasks:

- transformation into hounsfield units;
- segmentation and selection of scans with tuberculomas;
- cleaning of selected CT images from noise;
- use of an ensemble of segmentators;
- reading and selection of masks;
- determination of disease activity [18].

The next step of the proposed methodology is the selection of scans with pathologies – the problem of binary classification is solved. Such a classifier can be a small (up to 3 million parameters) convolutional neural network with a total processing time of several tens of seconds on a mid-range CPU (CPU). The use of MobileNetV2 architecture is an effective solution for processing images with limited computing resources. In this paper, transfer learning of this architecture, provided on the ImageNet dataset, is proposed for the selection of informative scans. The advantages of MobileNetV2 for this task are: small size -3–4 million parameters; the ability to use the model on weak CPUs and mobile devices; using Depthwise Separable Convolution allows to reduce the amount of calculations by 8–9 times; use of inverted residual bottleneck layers, which makes the calculation more memory efficient; scales on the ImageNet classification dataset allows our model to converge faster on the task of selecting informative scans. The algorithm for selecting scans with pathologies is as follows. Segmentation of lung viscera scans. Performs a trained MobileNetV2 network on all patient images. Selection and transfer to the stage of selection of tubercles only those images whose label is equal to 1 (the image is a tubercle) [19].

VII. Conclusions

The necessity of reducing the power of X-rays during the examination of patients is substantiated. It is shown that in this case there are problems with the quality of tomograms on which there are obstacles (extra elements) that do not reflect reality. The necessity of using artificial neural networks to prevent the presence of noise in the images is substantiated. CNN's multilayer noise reduction models are studied from a set of training images that are modeled using the XCAT phantom. To simulate a realistic noise model, Poisson noise is added to the synogram area. Both implemented architectures, the direct fully convoluted ResFCN network and the more powerful U-Net ResUNet architecture, have a residual connection for improved noise reduction. The results show that ResUNet is able to surpass ResFCN with a peak signal-to-noise ratio of 44.00 and 41.79, respectively.

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Sineglazov Victor. ORCID 0000-0002-3297-9060. Doctor of Engineering Science. Professor. Head of the Department.
Aviation Computer-Integrated Complexes Department, Faculty of Air Navigation Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine.
Education: Kyiv Polytechnic Institute, Kyiv, Ukraine, (1973).
Research area: Air Navigation, Air Traffic Control, Identification of Complex Systems, Wind/Solar power plant.
Publications: more than 660 papers.
E-mail: svm@nau.edu.ua

Kharchuk Yaroslav. Bachelor.
Aviation Computer-Integrated Complexes Department, Faculty of Air Navigation Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine.
Education: National Aviation University, Kyiv, Ukraine, (2021).
Research area: Identification of Complex Systems.
E-mail: yari.future@icloud.com

В. М. Синєглазов, Я. В. Харчук. Інтелектуальна система попередньої обробки зображень з комп'ютерних томографів

Штучні нейронні мережі можна навчати на корисних сигналах вихідних даних, але не можна навчати на зашумлених даних, тому зазвичай виконується шумоподавлення сигналів або компенсація помилок. У цій роботі реалізується модель шумоподавлення на основі штучних нейронних мереж для придушення компонентів з високим рівнем шуму, що важливо для оптимізації методів попередньої фільтрації. Як прикладне завдання, в якому потрібно придушення шумів, присутніх на зображенні, розглядається процес обробки сканів комп'ютерного томографа при медичних дослідженнях пацієнтів, які хворі на туберкульоз. У комп'ютерних томографах як випромінювання використовуються рентгенівські промені, що досить шкідливим для людини. Тому з метою зниження рівня опромінення потужність випромінювання знижують, В результаті знижується відношення корисного сигналу шум, що викликає появу шумів, які забруднюють зображення і ускладнюють його обробку. На зображенні з'являються додаткові тіні, що не існують об'єкти, що може призвести до постановки помилкового діагнозу. У роботі надано детальний опис роботи комп'ютерних томографів. Наведено опис топології згорткових нейронних мереж, що використовуються для обробки зображень. Розроблено алгоритм структурно-параметричного синтезу згорткових нейронних мереж, що використовуються при придушенні шумів зображень. Як навчальну вибірку були використані томограми хворих на туберкульоз, наданих Науково-дослідним інститутом пульмонології та фтизіатрії Національної академії медичних наук України.

Ключові слова: інтелектуальна система; туберкульозний; рентгенівські промені; згорткові нейронні мережі; комп'ютерна томографія; CycleGAN; штучні нейронні мережі; UNET; ResFCN; MobileNetV2.

Синєглазов Віктор Михайлович. ORCID 0000-0002-3297-9060.
Доктор технічних наук. Професор. Завідувач кафедрою.
Кафедра авіаційних комп'ютерно-інтегрованих комплексів, Факультет аеронавігації електроніки і телекомунікацій, Національний авіаційний університет, Київ, Україна.
Освіта: Київський політехнічний інститут, Київ, Україна, (1973).
Напрям наукової діяльності: аеронавігація, управління повітряним рухом, ідентифікація складних систем, вітроенергетичні установки.
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E-mail: svm@nau.edu.ua

Харчук Ярослав Володимирович. Бакалавр.
Кафедра авіаційних комп'ютерно-інтегрованих комплексів, Факультет аеронавігації електроніки і телекомунікацій, Національний авіаційний університет, Київ, Україна.
Освіта: Національний авіаційний університет, Київ, Україна, (2021).
Напрям наукової діяльності: ідентифікація складних систем.
E-mail: yari.future@icloud.com

В. М. Синеглазов, Я. В. Харчук. Интеллектуальная система предварительной обработки изображений с компьютерных томографов

Искусственные нейронные сети можно обучать на полезных сигналах исходных данных, но нельзя обучать на зашумленных данных, поэтому обычно производится шумоподавление сигналов или компенсация ошибок. В данной работе реализуется модель шумоподавления на базе искусственных нейронных сетей для угнетения компонентов с высочайшим уровнем шума, что принципиально для оптимизации способов предварительной фильтрации. В качестве прикладной задачи, в которой требуется подавление шумов, присутствующих на изображении, рассматривается процесс обработки сканов компьютерного томографа при медицинских исследованиях пациентов, больных туберкулезом. В компьютерных томографах в качестве излучения используются рентгеновские лучи, что является весьма вредным для человека. Поэтому с целью снижения уровня облучения мощность излучения снижают, В результате снижается отношение полезного сигнала шум, вызывающий появление шумов, загрязняющих изображение и усложняющих его обработку. На изображении появляются дополнительные тени, которые не существуют, что может привести к постановке ошибочного диагноза. В работе представлено подробное описание работы компьютерных томографов. Представлено описание топологии сверточных нейронных сетей, используемых для обработки изображений. Разработан алгоритм структурно-параметрического синтеза сверточных нейронных сетей, используемых при подавлении шумов изображений. В качестве учебной выборки были использованы томограммы больных туберкулезом, предоставленных Научно-исследовательским институтом пульмонологии и фтизиатрии Национальной академии медицинских наук Украины.

Ключевые слова: интеллектуальная система; туберкулезный; рентгеновские лучи; сверточные нейронные сети; компьютерная томография; CycleGAN; искусственные нейронные сети; UNET; ResFCN; MobileNetV2.

Синеглазов Виктор Михайлович. ORCID 0000-0002-3297-9060.
Доктор технических наук. Профессор. Заведующий кафедрой.
Кафедра авиационных компьютерно-интегрированных комплексов, Факультет аэронавигации электроники и телекоммуникаций, Национальный авиационный университет, Киев, Украина.
Образование: Киевский политехнический институт, Киев, Украина, (1973).
Направление научной деятельности: аэронавигация, управление воздушным движением, идентификация сложных систем, ветроэнергетические установки.
Количество публикаций: более 660 научных работ.
E-mail: svm@nau.edu.ua

Харчук Ярослав Владимирович. Бакалавр.
Кафедра авиационных компьютерно-интегрированных комплексов, Факультет аэронавигации электроники и телекоммуникаций, Национальный авиационный университет, Киев, Украина.
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Направление научной деятельности: идентификация сложных систем
E-mail: yari.future@icloud.com