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COMPUTER SCIENCES AND INFORMATION TECHNOLOGIES

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USING OF ARTIFICIAL INTELLIGENCE TO SOLVE THE PROBLEM OF CARDIOVASCULAR DISEASE DIAGNOSTICS

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Abstract—The article considers the feasibility of using artificial intelligence, artificial neural networks and machine learning in the tasks of classification and forecasting in the medical field. The directions in the field of health care in which artificial intelligence was used and the expediency of their use are considered. The analysis of the most frequent diseases among the population is made and the growth rate of diseases is shown. Proof of the success of neural networks when working with cardiovascular diseases, oncology, Covid-19. Machine learning algorithms that can be used to create an intelligent system for diagnosing cardiovascular diseases are considered. The characteristics that are advisable to use when creating such a system are presented. The requirements for the creation of an intelligent system that would allow to increase the level of qualification of health care professionals through their interaction with artificial neural networks are formed.

Index Terms—Artificial intelligence; artificial neural network; cardiovascular diseases; decision trees; deep learning; k-nearest neighbor method; machine learning algorithms.

I. Introduction

To date, cardiovascular disease is the most important cause of death in the world. According to the State Statistics Service of Ukraine for 2021, the three most common causes of death among Ukrainian citizens are cardiovascular disease, cancer, Covid-19 [1]. From the latest published data of the World Health Organization for the year 2020 we can see that the mortality rate from this disease is increasing (Fig. 1).
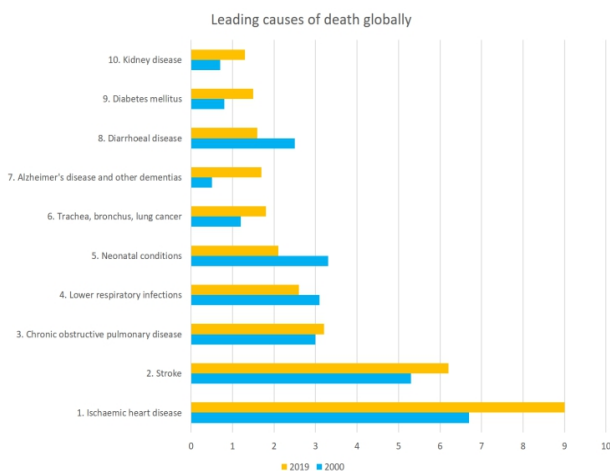

Fig. 1. Comparative statistics of mortality from the most common diseases 2000-2019

Every year more than 2 million people die of cardiovascular diseases [2]. Mortality from cardiovascular diseases ranks first not only in Ukraine, but also in the world as a whole, but because of the total number of deaths in relation to the entire population the problem is very relevant to Ukraine and Bulgaria (Fig. 2).
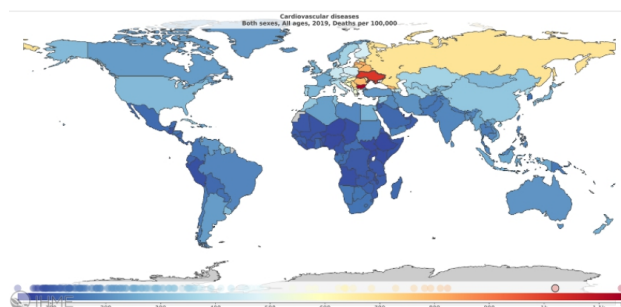

Fig. 2. Comparison of cardiovascular mortality statistics between countries 2019

II. Problem Statement

From the above data, we can conclude that there is a problem in identifying and treating patients to prevent them from dying from cardiovascular disease, but how can the healthcare system be improved? The main factors of quality diagnosis of patients are the availability of highly qualified

personnel and their provision with the necessary conditions for work. The health care system in Ukraine feels the shortage of qualified medical personnel more and more acutely [3]. An analysis of the downward trend in the number of medical personnel, followed by extrapolations of the data, suggests that by 2030 the staffing level of medical institutions in Ukraine will reach 75% of doctors, and that of nursing and junior medical personnel will reach 73.6% of the need. Already today there is a shortage of vacancies in healthcare in the amount of about 13 thousand positions. The reasons are aging of specialists, uneven number of doctors in the regions, which causes oversupply of specialists in big cities and deficit in villages, level of wages, and migration of specialists to other countries. If we compare average earnings of medical personnel with the countries-neighbors, in Belarus doctors receive 1.2 times higher wages, in Moldova – 2.2, in Romania – 4.7, in Poland – 5.8, in Hungary – 6.1, in Czech Republic – 8.1.

To overcome the problem, the optimal solution is to optimize the level of education of specialists, ensuring decent working conditions and material provision. This can be achieved through optimization and redistribution of finances, but in this case there will be an additional burden on medical personnel. To prevent the overload of people in the world actively use systems for decision-making, which allow one person to do more work while spending less time on it. In healthcare, there are intelligent systems that, based on artificial intelligence and medical knowledge bases, solve the problem of diagnosis, diagnosis and decision-making tactics for the treatment of patients without the participation of a medical specialist. Such systems currently solve simple tasks like analyzing computer scans or . The advantage is in processing large amounts of data and reducing the percentage of false positive diagnoses. Such systems can be based on machine learning algorithms such as artificial neural networks, deep learning, decision trees, and the k-nearest neighbor method.

Unlike artificial neural networks, deep learning uses a much larger number of layers, mostly 10 to 100 layers, while a neural network has 2-3 layers [4]. Each layer analyzes certain features from the dataset, forming a hierarchy from low level features to high level features, using learning algorithms with or without a teacher. As a consequence of this feature, neural networks cannot analyze complex parameters. Deep learning requires more data to train and more resources to execute. Layers have more neurons, allowing more parameters to be worked through.

Decision trees, by analyzing patients' medical records, identify the main symptom or trait, then create a tree that, depending on the traits, leads along branches to leaves that can no longer be separated. The branching process will continue until all leaves are reached [5]. In diagnosis with a decision tree, the patient will receive a series of questions. By analyzing the answers to them, decisions are made according to the traits that the algorithm has highlighted. The questions are built from more important to less important.

The k-nearest neighbor method is used to classify medical records in disease diagnosis [4]. During data analysis, medical records are categorized into groups of similar cards. Such groups represent classes of cases. When partitioning, the parameter k to determine the number of groups is specified. The main advantages of this method are that the reasoning for assigning a particular case to a particular group is clear to experts, and this approach is stable to abnormal cases.

III. FUNCTIONALITY OF ARTIFICIAL NEURAL NETWORKS

Due to the wide range of problems solved by BNMs (pattern recognition, decision making/management, clustering, prediction, approximation, data compression and associative memory) and their advantages over traditional computational methods (problem solving under uncertainty, resistance to noise in input data), flexibility in structure, high speed performance, adaptation to changes in the environment and fault tolerance), neural networks are becoming increasingly popular in creating new computational systems. SNM has disadvantages such as a large sample for training and duration of the process, the inability to make decisions in several stages. To date, the most promising use of artificial intelligence in the diagnosis of cardiovascular disease is the analysis of images and detection of cardiac abnormalities. Given the disadvantages of such systems, namely the impossibility of solving the problem in one action, it is necessary to divide the work of NM into stages: identification of signs of cardiac diseases by analyzing images by a neural network and making decisions based on the signs. That is, divide one task into two neural networks, which perform it gradually. For tasks such as image analysis by a neural network, deep learning is used, namely convolutional neural networks, a type of

deep artificial neural network architecture aimed at effective recognition and analysis of visual images.

A convolutional neural network is a class of artificial neural networks that uses convolutional layers to filter input data to obtain useful information. The convolution operation involves combining the input data (object map) with a convolution kernel (filter) to form a transformed object map. Filters in layers are modified based on learned parameters to extract the most useful information for a particular task. The convolution nets are tuned to find the best function depending on the task. When we have similarly shaped objects, the system will recognize them by their color rather than their shape, because the variation in color is much higher than the variation in shape.

Applications of convolutional neural networks include various image processing systems (image recognition, image classification, video labeling, text analysis) and language processing systems (language recognition, natural language processing, text classification), as well as advanced artificial intelligence systems.

A convolutional network consists of an input layer, a source layer and one or more hidden layers. A convolutional network differs from a conventional neural network in that the neurons in its layers are arranged in three dimensions (width, height and depth). This allows the CNN to transform the input volume in three dimensions into the raw data. Hidden layers are a combination of convolution layers, union layers, normalization layers, and fully connected layers. CNNs use multiple message layers to filter input volumes into higher levels of abstraction.

Today, CNNs use initial modules that use 1×1 convolutional cores to further reduce memory consumption while providing more efficient computation (and hence learning). This makes CNNs suitable for a number of machine learning applications.
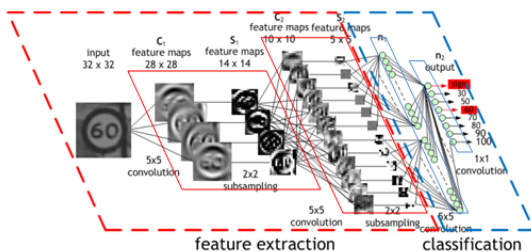

Fig. 3. Image of the convolutional neural network

The activation function in a neural network applies a non-linear transformation of weighted inputs. A popular activation function for CNNs is ReLu or a rectified linear function that nullifies negative inputs. The initial modules in CNN allow you to speed up the computation. This is done using 1×1 convolutions with a small object map size, for example, 192 28×28 object maps can be reduced to 64 28×28 object maps using 64 1×1 convolutions. Because of the reduced size, these 1×1 convolutions can be accompanied by large 3×3 and 5×5 "packs". In addition to the 1×1 pack, maximum aggregation can also be used to reduce dimensionality. In the input data of the initial module, all large convolutions are combined into an extensive object map, which is then fed to the next level (or initial module).

Pulling is a procedure that reduces the input data over a certain area to a single value. Pulling provides basic invariance of rotations and translations and improves the ability to detect objects in convolutional networks. For example, a face in an image that is not in the center of the image, but slightly offset, can still be detected by convolutional filters, since the information is transferred to the right place through a pooling operation. The larger the size of the pooling area, the more the information is condensed, resulting in small networks that fit more easily into the GPU memory. However, if the object pooling area is too large, too much information is thrown away, and predictive performance is reduced.

IV. DIAGNOSIS OF DISEASES BY A CARDIOLOGIST

A cardiologist is responsible for diagnosing and prescribing therapy for conditions such as:

- *Hypertension*. Constantly elevated BP, which causes unpleasant symptoms and can lead to crises.
- *Heart failure*. Reduced ability of the heart muscle to perform its primary function of pumping blood.
- *Increased cholesterol levels*, which can lead to plaque formation and blockage of blood vessels.
- *Myocarditis* – inflammation of the heart muscle.
- *Cardiomyopathy* – damage to the heart muscle;
- *Heart defects* – congenital or acquired abnormalities and deformities of the myocardium and coronary vessels.
- *Coronary heart disease*, when the heart does not get enough oxygen.
- *Angina pectoris* – insufficient blood supply to the myocardium.

- *Rehabilitation* after a heart attack and stroke.
- *Arrhythmia* of various kinds – an accelerated or decreased rhythm of heart contractions.

To identify the above-mentioned diseases, the doctor should collect the patient's medical history and prescribe additional examinations depending on the preliminary diagnosis:

- *coronarography* – an *x*-ray of the coronary arteries to establish coronary heart disease;
- *electrocardiography* (ECG) to determine heart rhythm parameters;
- *echocardiography* or ultrasound of the heart to determine the size and structure of the heart and assess its function;
- *doppler ultrasound* – shows vascular function;
- *daily ECG and BP monitoring* by Holter shows changes in blood pressure and heart rhythm during the day;
- *laboratory examination* (general blood and urine tests, blood chemistry, lipid profile, coagulogram and other specific indicators).

V. CONCLUSIONS

Artificial neural networks are the most accurate method, but potentially deep learning can develop the same accuracy. In terms of speed, artificial neural networks are the worst, while k-nearest neighbor methods and decision trees showed good speed. Fuzzy logic based systems showed average speed and accuracy relative to other algorithms. It is not possible to determine how much the human factor (quality of expert inference) influenced this system.

If the tasks need a large number of layers, for example, analysis of X-rays, MRI, it is better to use systems with deep learning.

The main advantage of machine learning algorithms is the identification of hidden relationships of analysis components and the identification of the most important diagnostic parameters.

Depending on the operating principle and requirements for an intelligent system, a machine learning algorithm should be selected. There are studies that have identified key characteristics for learning systems depending on the method.

Studies have shown that the application of diagnosis, diagnosis and choice of treatment tactics is appropriate for the field of health care. The greatest amount of research has focused on cancer and Covid-19 and in these areas the use of artificial intelligence has proven effective, but this has not meant that the use of AI will be effective for cardiovascular disease. However, University of Nottingham research has proven in practice that, compared to the standard approach, machine learning algorithms are better at identifying cardiovascular disease and excluding patients who do not have the disease.

To date, there is no intelligent system that can be practically used by any cardiologist, and existing projects are limited to studies within institutions where they are conducted, so there is a need to create such a system.

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О. І. Чумаченко, С. О. Коломоєць. Використання штучного інтелекту для розв'язання задачі діагностики серцево-судинних захворювань

У статті розглянуті питання доцільності використання штучного інтелекту, штучних нейронних мереж та машинного навчання в задачах класифікації та прогнозування в медичній сфері. Розглянуто напрямки у сфері охорони здоров'я, у яких штучний інтелект використовувався та доцільність їх використання. Зроблено аналіз найчастіших захворювань серед населення і показано темпи зростання захворювань. Доведення успішності роботи нейронних мереж при роботі з серцево-судинними захворюваннями, онкологією, Covid-19. Розглянуто алгоритми машинного навчання, що можуть використовуватися при створенні інтелектуальної системи діагностики серцево-судинних захворювань. Представлено характеристики, які доцільно використовувати при створенні такої системи. Сформовано вимоги для створення інтелектуальної системи яка б дозволила підвищити рівень кваліфікації спеціалістів сфери охорони здоров'я за рахунок їхньої взаємодії з штучними нейронними мережами.

Ключові слова: штучний інтелект; штучна нейронна мережа; серцево-судинні захворювання; дерева прийняття рішень; глибинне навчання; k-метод найближчого сусіда; алгоритми машинного навчання.

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Е. И. Чумаченко, С. А. Коломоец. Использование искусственного интеллекта для решения задачи диагностики сердечно-сосудистых заболеваний

В статье рассмотрены вопросы целесообразности использования искусственного интеллекта, искусственных нейронных сетей и машинного обучения в задачах классификации и прогнозирования в медицинской сфере. Рассмотрены направления в сфере здравоохранения, в которых искусственный интеллект использовался и целесообразность их использования. Сделан анализ самых частых заболеваний среди населения и показаны темпы роста заболеваний. Доказана успешность работы нейронных сетей при работе с сердечно-сосудистыми заболеваниями, онкологией, Covid-19. Рассмотрены алгоритмы машинного обучения, которые могут использоваться при создании интеллектуальной системы диагностики сердечно-сосудистых заболеваний. Представлены характеристики, которые целесообразно использовать при создании такой системы. Сформированы требования для создания интеллектуальной системы, которая бы позволила повысить уровень квалификации специалистов сферы здравоохранения за счет их взаимодействия с искусственными нейронными сетями.

Ключевые слова: искусственный интеллект; искусственная нейронная сеть; сердечно-сосудистые заболевания; деревья принятия решений; глубинное обучение; k-метод ближайшего соседа; алгоритмы машинного обучения.

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