International Journal of Electrical and Computer Engineering (IJECE)
Vol. 13, No. 6, December 2023, pp. 6673~6680
ISSN: 2088-8708, DOI: 10.11591/ijece.v13i6.pp6673-6680

Detection of heart pathology using deep learning methods

Akgul Naizagarayeva[1], Gulzira Abdikerimova[2], Aigul Shaikhanova[3], Natalya Glazyrina[4], Gulmira Bekmagambetova[5], Natalya Mutovina[6], Assel Yerzhan[7], Adilbek Tanirbergenov[8]

[1]Department of Information Systems, Faculty of Computer Systems and Vocational Education, S. Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan
[2]Department of Information Systems, Faculty of Information Technology, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan
[3]Department of Information Security, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan
[4]Department of Computer and Software Engineering, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan
[5]Department of Information Technology, Kazakhstan University of Technology and Business, Astana, Kazakhstan
[6]Department of Information and Computing Systems, Karaganda Technical University, Karaganda, Kazakhstan
[7]Department of Telecommunications and Innovative Technologies, Almaty University of Power Engineering and Telecommunications named after G. Daukeev, Almaty, Kazakhstan
[8]Department of Algebra and Geometry, L. N. Gumilyov Eurasian National University, Astana, Kazakhstan

Article Info

Article history:

Received Apr 13, 2023
Revised May 12, 2023
Accepted May 25, 2023

Keywords:

Automatic diagnosis
Convolutional neural network
Electrocardiogram
Long short-term memory
Machine learning
Recurrent neural network

ABSTRACT

In the directions of modern medicine, a new area of processing and analysis of visual data is actively developing - a radio municipality - a computer technology that allows you to deeply analyze medical images, such as computed tomography (CT), magnetic resonance imaging (MRI), chest radiography (CXR), electrocardiography and electrocardiography. This approach allows us to extract quantitative texture signs from signals and distinguish informative features to describe the heart's pathology, providing a personified approach to diagnosis and treatment. Cardiovascular diseases (SVD) are one of the main causes of death in the world, and early detection is crucial for timely intervention and improvement of results. This experiment aims to increase the accuracy of deep learning algorithms to determine cardiovascular diseases. To achieve the goal, the methods of deep learning were considered used to analyze cardiograms. To solve the tasks set in the work, 50 patients were used who are classified by three indicators, 13 anomalous, 24 nonbeat, and 1 healthy parameter, which is taken from the MIT-BIH Arrhythmia database.

Corresponding Author:

Gulzira Abdikerimova
Department of Information Systems, Faculty Information Technology, L. N. Gumilyov Eurasian National University
010000 Astana, Kazakhstan
Email: gulzira1981@mail.ru

1. INTRODUCTION

Modern deep learning methods are widely used to detect heart pathology. These methods can be used to detect heart disease at an early stage and to predict the risk of cardiovascular disease. One example of the application of deep learning in cardiology is the use of neural networks for the analysis of electrocardiograms (ECGs). The neural network can be trained to recognize abnormalities in the ECG signal and highlight signs that are associated with certain heart diseases. There are also deep learning algorithms for analyzing medical image data (such as ultrasound and x-rays of the heart) and detecting heart pathology. Overall, deep learning can be a useful tool for detecting cardiac pathology and can help improve the accuracy of diagnosing and predicting cardiovascular disease.

In this article, deep learning algorithms including convolutional neural networks (CNNs), fully connected neural networks (DENSE), recurrent neural networks (RNN), and multilayer perceptrons (MLPs) have been considered in the context of their application to heart disease prediction. CNNs can be used to process medical images of the heart, such as ultrasounds and x-rays, and to extract features associated with certain heart diseases. Such neural networks have been successfully used to diagnose heart diseases such as hypertension, arrhythmias, and valvular disease. DENSE can be used to analyze various biomarkers and medical parameters such as heart rate, blood pressure, and cholesterol levels to predict heart disease risk. Such neural networks have been successfully used to predict the risk of developing coronary heart disease and myocardial infarction. RNNs long short-term memory (LSTM) can be used to analyze time series data such as ECG signals to detect abnormalities in heart rate and predict cardiovascular risk. Such neural networks are successfully used to diagnose cardiac arrhythmias. MLPs can be used to predict heart disease risk based on various biomarkers and medical variables, including age, gender, family history, and other risk factors. For predicting cardiovascular disease (CVD) risk using MLP, the input data may contain information on various biomarkers such as cholesterol, blood pressure, body mass index, and other physiological parameters. MLP is a general term that describes a neural network with multiple layers, including input, hidden, and output layers. A DENSE (dense) layer is a specific type of layer that is used in MLP, where each neuron is connected to all the neurons of the previous layer. Thus, the DENSE layer provides a complete connection between the neurons of two adjacent layers. Such neural networks have been successfully used to predict the risk of developing coronary heart disease and myocardial infarction. The experiment used data from an open database and took into account the results of predicting heart disease using deep learning, which depended on the quality and quantity of data. The detection of heart pathology using machine learning is a very relevant and important task in medical science. That is, when solving the problem of increasing incidence, the complexity of diagnosis, processing large amounts of data, and optimizing treatment is to identify heart diseases in the early stages, prevent the development of complications and improve the prognosis of the disease using machine learning algorithms.

2. LITERATURE REVIEW

Researching the human biological field is one of the most important diagnostic techniques in modern medicine. The human biological field includes many acoustic [1]–[3], thermal [4], [5], and electromagnetic [6]–[8] radiations, the study of each of which makes it possible to identify the pathology of the functioning of the organism as a whole, individual organ, and organ systems. During the examination, diagnosticians receive huge amounts of data, the processing of which takes a long time. Also, traditional clinical [9] and laboratory diagnostic methods detect the disease when the pathology has already seriously developed. In addition, the most accurate methods of medical diagnostics are financially expensive, rather complicated, and can also be invasive, their use causes discomfort to the patient, and in extreme cases, they can lead to various complications and even a threat to life. Therefore, the issue of reducing the time for analyzing the data obtained and early detection of the pathology of cardiovascular disease is still relevant. One of the most promising areas that allow diagnosing diseases is the use of neural network modeling in medical diagnostics. In this work, deep learning methods were used to identify anomalous observations, and an effective one was determined, which makes it possible to detect with a high degree of accuracy examples that stand out from the general pattern and introduce an error into the learning process. Eliminating or correcting such observations allows you to increase the learning rate of the neural network model, as well as the accuracy of the resulting model. Artificial intelligence systems based on artificial neural networks show certain success in the analysis and classification of large data sets and allow not only to automate the analysis processes but also to produce to identify of certain patterns of change in various features [10]–[12].

The study aims to improve the accuracy of predicting the pathology of heart disease by ECG using the studied neural network artificial intelligence. To achieve this goal, the applicability of deep learning methods was studied and a comparative analysis was made between these methods. The data used in this work was taken from MIT-BIH Arrhythmia, which is a biomedical research database run by the National Institute of Bioengineering and the National Institute of General Medical Sciences [13]. The resource was created in 1999 by a group of scientists, physicians, and educators at the Beth Israel Medical Center, the Massachusetts Institute of Technology, Harvard Medical School, Boston University, and McGill University. During the experiment, to determine the effectiveness of deep learning methods such as convolutional neural network [14]–[16], recurrent neural network [17]–[19], long short-term memory [20]–[22], multilayer perceptron [23], [24], data from 50 patients were taken, classified according to three indicators, 13 abnormal, 24 abnormal and 1 healthy parameter.

3. METHOD

The issue of electro-cardio signal classification is to identify informative signs and find their dependence on the corresponding heart disease or its absence. The main signs of cardiac dysfunction are deviations from the norm in the duration of the interval between positive waves (RR), variability in the duration and amplitude of the complex Q is the first negative wave, R is the first positive wave, S is the first negative wave after the R wave [25]. Artificial intelligence (AI) is an approach that emphasizes the development of intelligent machines that think and act in a similar way to human cognitive behavior. In this paper, artificial neuron models were considered to accept input, process it, pass it through a sigmoid activation function, and return an activated output, as shown in Figure 1. Deep learning is a subset of AI machine learning that uses multiple layers to extract features from input layers. Deep learning algorithms are used because of their efficiency on large amounts of data and their ability to handle large amounts of unstructured data. Deep neural networks are well-established in several fields such as bioinformatics, computer vision, natural language processing (NLP), machine translation, and speech and sound recognition. The task of a neural network is to receive input data, then perform calculations and produce output data. The purpose of a neural network is to take input, then perform calculations and produce output to solve complex real-world problems such as image enhancement and object scaling, ECG signal classification. For image or object recognition, convolutional neural networks give good results. During the experiment, deep learning algorithms were used: CNN, fully connected layer, LSTM, and MLP as shown in Figures 1(a) to 1(d). In this paper, CNN, DENSE, LSTM, and MLP algorithms were considered-these are various deep learning algorithms that can be used to detect cardiac pathology, including tachycardia.

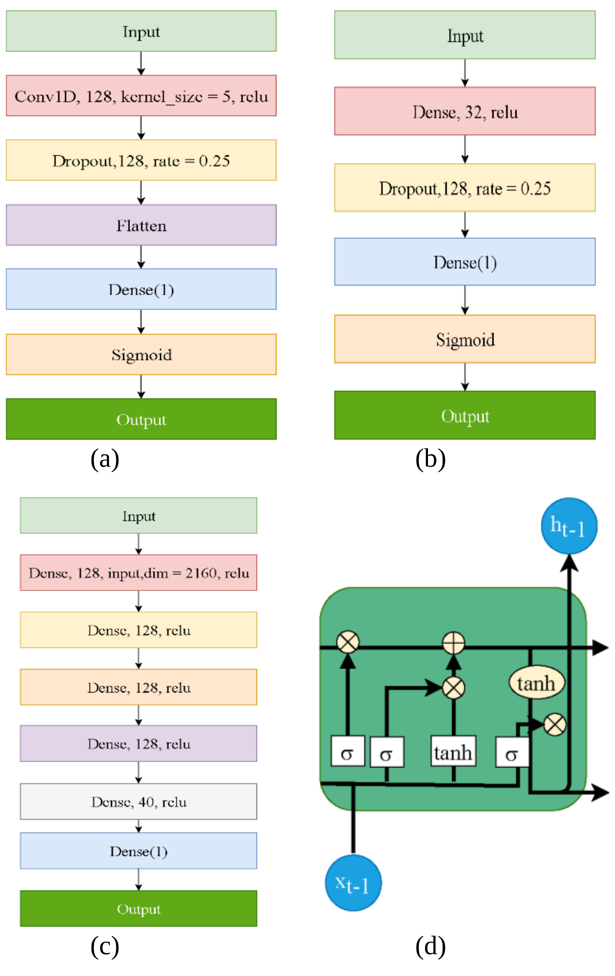


Figure 1. The architecture of deep learning algorithms (a) CNN, (b) DENSE, (c) LSTM, and (d) MLP

CNN can be used to process and classify images, including ECG signals. It can automatically extract features from the input data, which allows it to process large amounts of data more efficiently as shown in Figure 1(a). DENSE, or a fully connected neural network, can be used to classify data, including ECG signals. It has a simple architecture and can be easily customized for certain types of classification tasks as shown in Figure 1(b). MLP is the main type of neural network that can be used to classify data. It consists of several layers of neurons and can be used to solve various types of classification problems, including the detection of tachycardia on ECG signals as shown in Figure 1(c). LSTM can be used to process time series such as ECG signals. It can take into account and remember relationships between data at different time steps, which makes it useful for classifying ECG signals, including the detection of tachycardia as shown in Figure 1(d).

With basic knowledge of statistics, linear algebra, calculus, machine learning methods, and Python libraries like Matplotlib, NumPy, Pandas, and SciPy, neural network frameworks like Keras, and Tensor Flow developed deep learning models are designed for prediction, classification, understanding, perception of objects of the subject area under consideration. During the experiment, the data sets taken were classified by parameters. Data augmentation techniques help researchers train models on various datasets, especially images such as cropping, padding, and reflection to train large neural networks. The use of already available architectures with modified layers, such as CNN, DENSE, LSTM, and MLP, made it possible to increase the accuracy of predicting cardiovascular diseases. Although all of these algorithms can be used to detect cardiac pathology, including tachycardia, each of them has its advantages and disadvantages and must be properly configured and trained for a specific task. In addition, it must be taken into account that the diagnosis of heart disease requires high qualifications and experience of a cardiologist.

Recordings were digitized at a rate of 360 samples per second per channel with 11-bit resolution in the 10 mV range. Two or more cardiologists independently annotated each entry; the contention was resolved to obtain machine-readable reference annotations for each stroke (about 110,000 annotations in total) included in the database. For the experiment, 109,099 data sets were used as the number of samples, of which 73,096 were used as the training data set, and 36,003 were used as the test data set.

4. RESULTS AND DISCUSSION

A signal was built around one of the anomalous impacts using deep learning algorithms. Of the 24 parameters considered, such as beat and non-beat annotations, such as normal ventricular fusion, pacing, normal pacing fusion, ventricular flutter/fibrillation onset, signal termination, and cardiac electrical activity during ventricular contraction QRS, where 30% have abnormal values. Figure 2 shows an ECG of the rhythm of a diseased heart, where an abnormal value is seen at the second minute.

During the experiment, the types of heart contractions, such as tachycardia and bradycardia, were considered. Table 1 presents the results of a comparative analysis of each model and the percentage accuracy of detection of cardiovascular disease, tachycardia. When training the DENSE deep learning algorithm, we experimented by adding new layers. When adding layers, the prediction accuracy increased to 5 layers. When the neural network was increased to 6 layers, the accuracy of the result decreased significantly. Thus, the model was effectively trained on 5 layers.

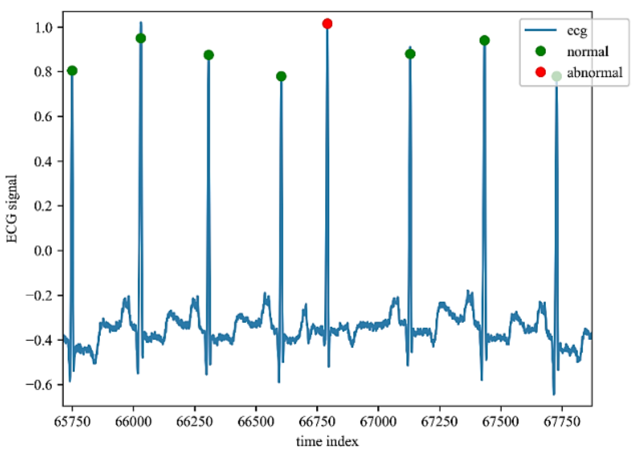
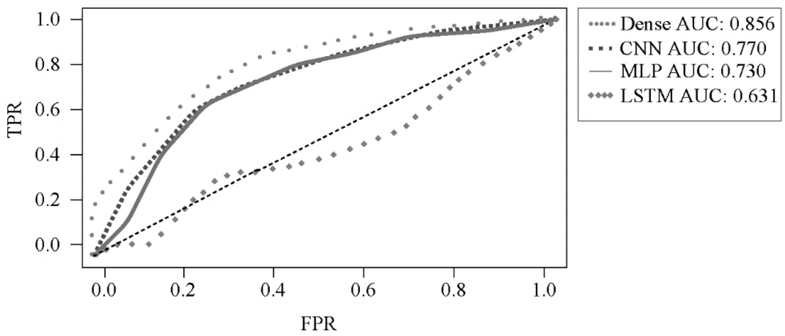


Figure 2. Sick heart rhythm

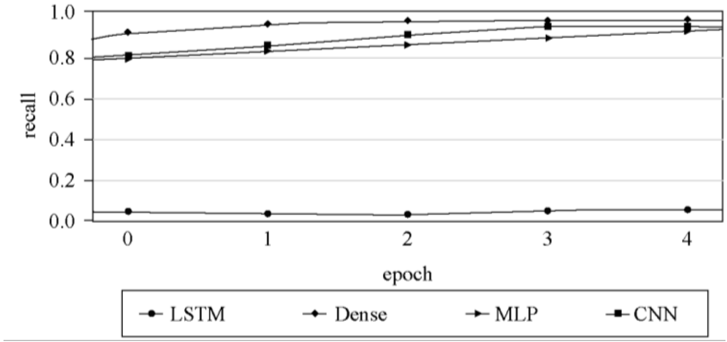
Table 1. Accuracy in predicting the pathology of heart disease

Types of heartbeat methods	LSTM	DENSE	MLP	CNN
Prediction of pathologies of cardiovascular diseases	63.1%	85.6%	73%	77%

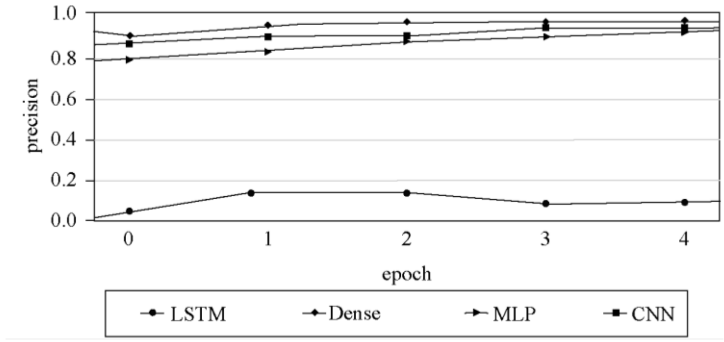
Figure 3 shows the accuracy of the training result for metrics such as accuracy Figure 3(a), F-score Figure 3(b), sensitivity Figure 3(c) for each model in a graph. The DENSE algorithm proved to be the most efficient among the deep learning algorithms reviewed in this study. Although these considered models are effective in other applications, they are ineffective for predicting cardiovascular disease.



(a)



(b)



(c)

Figure 3. Graph of the accuracy of predicting heart disease according to the considered algorithms (a) accuracy, (b) recall, and (c) F-score

In this work, an experiment was conducted with one of the deep learning algorithms using dense layers (dense neural network) to determine tachycardia based on the analysis of ECGs of a patient. To do this, patient ECG data from an open-source database was used as input to a neural network, where each ECG signal is treated as a separate vector of input values. Next, using dense layers of neurons, the network will be trained to recognize patterns associated with tachycardia. Creation of a neural network with several hidden dense layers trained to recognize more complex patterns such as morphological features associated with tachycardia. For example, the first hidden layers can detect simple shapes such as peaks and waves, while deeper layers can be used to find more complex feature combinations. To train such a model, an open-source ECG dataset was used, which for MIT-BIH arrhythmias contains 48 half-hour fragments of two-channel ambulatory ECG recordings obtained from 47 persons examined by the BIH Arrhythmia Laboratory from 1975 to 1979. The model was trained using the backpropagation method, which allows you to optimize the neural network weights to minimize the error between the predicted values and the target values. The model was trained using the backpropagation method, which allows you to optimize the neural network weights to minimize the error between the predicted values and the target values. Once trained, the models can be used to classify new ECG data and determine whether a patient has tachycardia. Our experiments have shown that DENSE achieves a high result on all metrics, i.e., 85.6% accuracy, 96.5% F-score and 97.7% recall. As well as deep learning methods optimized with the addition of layers can lead to highly accurate models designed for both clinical and research use.

As a result, not only the number of examples was taken into account, but also the quality of the data used to train and test the model, as well as the parameters of the model itself and its ability to generalize to new data. If tachycardia is detected on ECG signals, a large data set must be used to train the model, including both normal ECG signals and ECG signals with various types of tachycardia. This allowed the models to better recognize patterns in normal and abnormal ECG signals and make more accurate predictions. In addition, to assess the effectiveness of the model, it is necessary to use quality metrics, such as accuracy (accuracy), sensitivity (recall), specificity (specificity), F-score (F1-score), and others. These metrics made it possible to assess in this work how accurately the model can classify ECG signals and detect the presence of tachycardia.

If the model is trained on a sufficiently large and diverse data set, using efficient deep learning algorithms, then high accuracy and sensitivity in detecting tachycardia on ECG signals can be achieved. For example, research has shown that the use of deep neural networks such as CNN and DENSE can be more than 75% accurate in detecting tachycardia on ECG signals. However, it should be taken into account that in practice the accuracy may be lower due to various factors such as noise in the data, problems with the calibration of ECG devices, the presence of other pathological conditions that affect the shape of the ECG signal. Therefore, when using deep neural networks to detect tachycardia on ECG signals, it is necessary to take into account the limitations of the model and evaluate it on various data sets to determine its real effectiveness in diagnosing heart diseases.

5. CONCLUSION

The methods of deep learning and their applicability for performing the tasks of classifying an electro-cardio signal are considered. The task of classification and its specification of ECG was investigated. Neural networks are a promising method for classifying unlabeled data as well. Some of their types, especially convolutional neural networks, favorably differed by the absence of the need for data preprocessing. The biomedical database PhisioNet was also studied, providing systematic data on diagnostic measurements that can be used to form training and test samples.

To improve the accuracy of determining the pathology of cardiovascular diseases by ECG, several methods of deep learning were considered, and a comparative analysis of these methods was made. As a result of the experiments, a higher accuracy in determining the disease by the DENSE method was obtained at 85.6%. Four deep learning methods were used to improve the accuracy of predicting the development of heart disease. These methods are effective in predicting processes with complex correlations between input parameters. To further create an automated system for predicting heart disease by ECG, a deep learning method-MLP can be built into the diagnostic system. In many areas of science, problems are important. However, in the field of medicine, it is necessary to be more accurate in diagnosing diseases. That is why it is necessary to constantly modify new technological algorithms used in solving problems in the field of medicine, for example, it is important to improve training parameters, compare deep learning algorithms to analyze the improvement of results, and train the training set with a set of informative features.

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BIOGRAPHIES OF AUTHORS

Akgul Naizagarayeva 2018-2021 Eurasian National University. Gumilyova LN, graduated from doctoral studies in the specialty "Mathematics and computer mathematical modeling". Currently, she is a senior lecturer at the Department of Information Systems of the Kazakh Agrarian Research University named after S. Seifullin. Her research interests are object-oriented programming, database management systems, mathematical modeling, and artificial intelligence. She can be contacted at email akgul_1985@mail.ru.

Gulzira Abdikerimova received her Ph.D. in 2020 in Information Systems from L.N. Gumilyov Eurasian National University, Kazakhstan. Currently, she is an associate professor of the Department of Information Systems at the same university. Her research interests include image processing, computer vision, satellite imagery, artificial intelligence and machine learning. She can be contacted at email gulzira1981@gmail.com.

Aigul Shaikhanova received a bachelor's degree in Automation and Control, a master's degree in Computer Science (1998, 2011, respectively). Ph.D. in Computer Science and Software (2015) and Associate Professor in Informatics, Computing and Management (2021). Research interests: cybersecurity, computer networks, internet of things, neural networks, computer vision. Has more than 80 publications, including 4 teaching aids, 2 monographs and more than 80 scientific papers. She can be contacted by email shaikhanova_ak@enu.kz.

Natalya Glazyrina graduated from the Institute of Automation, Telecommunications and Information Technology of Omsk State Transport University in 2003. She defended her doctoral thesis on Computer Technology and Software in 2015. From 2016 to the present time, she is an associate professor of the Department of Computer and Software Engineering at L.N. Gumilyov Eurasian National University. She has authored more than 50 papers. Her research interests include mathematical and computer modeling, artificial intelligence, automation of technological processes. She can be contacted at email glazyrina_ns_1@enu.kz.

Gulmira Bekmagambetova Ph.D., Associated Professor. Currently, she works at the Kazakhstan University of Technology and Business at the Department of Information Technology. Has more than 20 years of scientific and pedagogical experience and more than 20 scientific papers, including 1 article based on Scopus, 2 textbooks with ISBN, 5 manuals and developments. Member of the "Modern education and research institute", Registration No. 0660.570.790 Brussels, Belgium. She can be contacted at email g_bek@mail.ru, gulmirabekmagam@gmail.com.

Natalya Mutovina candidate of Technical Sciences, Assistant Professor. Currently working at the Karaganda Technical University at the Department of Information and Computing Systems. Has more than 20 years of scientific and pedagogical experience, publication of an article in the Scopus database. Professor of the Russian Academy of Natural Sciences. She can be contacted by email mutovina_natalya@mail.ru.

Assel Yerzhan in 2003, she graduated from the Almaty Institute of Energy and Communications with a degree in industrial electronics. In 2004, she received a Master's degree in Radio Electronics and Telecommunications. In 2013, she graduated from the doctoral program "Kazakh National Technical University named after K.I. Satbayev", specialty 6D071900 – "Radio engineering, electronics and telecommunications". From 2014 to the present, she has been a Doctor of Philosophy PhD in the specialty 6D071900 "Radio Engineering, Electronics and Telecommunications" of the Gumarbek Daukeev Almaty University of Energy and Communications. She is the author of more than 40 works. Her research interests include circuit engineering in telecommunications, wireless communications, mobile communication systems, GSM and mobile systems management, sensor networks, 5G and mobile communication technologies. She can be contacted by email erjanasel@gmai.com, a.erzhan@aues.kz.

Adilbek Tanirbergenov candidate of Technical Sciences, specialty 05.17.08 – Processes and devices of chemical technology. Successfully defended his Ph.D. thesis on the topic "Research of dust collection and heat transfer processes in intensive apparatuses with aerodynamic flows". Currently, Tanirbergenov A. Zh. works at the L.N. Gumilyov ENU, Acting Associate Professor of the Department of Algebra and Geometry. Research interests: modern innovative technologies in education and science, cryptology, cybersecurity. He has more than 30 publications, including: 2 articles in the journals of the SCOPUS database. He can be contacted at email: t.adilbek@mail.ru.