

ANNOTATION

of the dissertation by Mukhanov S.B. "Development application for high precision patterns," submitted for the degree of Philosophy Doctor (PhD) in the specialty of 6D070400 – Computer systems and software engineering.

Currently, more and more research are focused on solving problems using computer vision libraries and artificial intelligence tools. The most common are solutions and approaches using models of machine and deep learning of artificial neural networks for recognition of gestures of the Kazakh sign alphabet based on methods of training with a teacher and deep learning for processing sequential data. The object of research is the Kazakh sign alphabet for building communication between people with disabilities. The subject of research is machine learning methods and models of artificial neural networks and deep learning for the classification and recognition of gestures. Research methods are Data Science, Machine Learning, Deep Learning, Neural networks, and Computer Vision.

Image recognition is an image on which an object is located. Since the object is abstract (the object can be any form shown in the picture). We decided to study one of the current directions - recognition of gestures. To recognize the Kazakh sign language, first, you need to study the Kazakh sign alphabet. To train a neural network to recognize Kazakh sign language, it is necessary to collect data (dataset) in the format of images indicated by hand gestures. Gesture recognition is a task of classification, which is one of the directions of types of image recognition. The fundamental basis of recognition is the theory of pattern recognition.

Research goal. Develop and apply high-precision image recognition methods. For this, it is necessary to use artificial intelligence tools, namely algorithms and libraries (Python programming language) for working with machine learning and deep learning neural networks. Collect data for training and pre-process it for training neural networks. It is important to produce mathematical calculations for calculating gradient functions and learning algorithms for backpropagation and activation functions for each neuron. Apply an empirical approach to the development of the own architecture of neural network models for training parameters and hyperparameters. The architecture of this model can vary both in depth and width of the neural network, so we arbitrarily determine the number of learning parameters. In the dissertation, the main attention is paid to the study of teaching methods with a teacher, the method of deep learning, the task of classification and recognition of gestures trained on own data (images obtained and divided into frames from a video sequence, taken by a web camera or a mobile device). These methods allow to significantly expand the range of tasks that can be effectively solved in real time in the field of gesture recognition. Software development will allow testing the effectiveness of the trained model and applying it for laboratory purposes, adjusting improve this model. Achieving the set goal will lead to increased efficiency and expansion of capabilities of modern systems of computer vision and gesture recognition.

To achieve the goal, it was necessary to solve the following tasks:

1. Collect data (images of letters represented in the form of hand gestures of the Kazakh gestural alphabet) and pre-processing in order to prepare a training set for machine and deep learning methods.

2. Analysis of deep learning architecture and application of methods for gesture recognition.

3. Train the neural network to recognize the Kazakh sign alphabet on its own data (images).

4. Make a comparative convolutional and recurrent neural network of deep learning.

5. Develop software for recognizing gestures (Kazakh sign alphabet) in real time.

The object of research is the training of an artificial neural network to recognize the Kazakh sign alphabet with the help of artificial intelligence tools, namely, machine learning methods.

The subject of research is the software of the gesture recognition system, developed on the basis of a trained model of deep neural networks.

Scientific novelty of research is determined by:

1. Collected data in the format of images of hand gestures and for training models of artificial neural networks.

2. The training model of deep learning for the recognition of the Kazakh gestural (dactyl) alphabet.

3. The proprietary architecture of the hybrid model is built on the basis of the method of learning with a teacher of a convolutional neural network and the method of deep learning of a recurrent neural network.

4. Developed software for recognizing the Kazakh sign alphabet.

Scientific provisions, applicable to protection:

1. Collected data in the format of images of hand gestures for training models of artificial neural networks.

2. Trained models of machine and deep learning for recognition of the Kazakh sign alphabet.

3. The proprietary architecture of the hybrid model is built based on the method of learning with a teacher of a convolutional neural network and the method of deep learning of a recurrent neural network.

4. Developed software for recognizing the Kazakh sign alphabet.

Theoretical and practical significance. The theoretical significance of the study is the development and justification of a new approach to solving the task of classification for the recognition of the Kazakh sign alphabet, trained on its own collected data for training a model of an artificial neural network on algorithms/methods of machine learning.

The practical significance lies in the development of software for recognizing the Kazakh sign language alphabet in real time.

Reliability of results. The reliability of the results of the dissertation is confirmed by the correctness of the research tasks and the application of mathematical formulas and calculations, as well as the calculation and obtaining of results by means of training the own neural network on the principle of operation of the multilayer perceptron architecture, developing a hybrid architectural model of convolutional and recurrent

neural network and obtaining trained and test results of on the basis of such metrics as: accuracy, recall, precision and f1-score, confusion matrix (error matrix), as well as software implementation and computational experiments conducted in the PyCharm and Jupyter Notebook development environments in the Python programming language and a computer library vision and machine learning.

Theoretical and practical significance. The theoretical significance of the work lies in the development and justification of a new approach to solving the classification problem for a multi-class 42-class classification of the Kazakh sign language alphabet, trained on an artificial neural network model using machine learning methods.

The practical significance involves the development of software (a desktop application) for real-time recognition of the Kazakh sign language alphabet.

Reliability of results. The reliability of the results of the dissertation is confirmed by the correctness of the formulated research problems, the application of mathematical formulas and calculations, as well as the computation and acquisition of results through training a custom neural network based on the architecture of a multilayer perceptron. A hybrid architectural model of convolutional and recurrent neural networks was developed, and trained and test results were obtained based on metrics such as accuracy, recall, precision, and f1-score, along with a confusion matrix. The research also involved software implementation and computational experiments conducted in the PyCharm and Jupyter Notebook development environments using the Python programming language and libraries for computer vision and machine learning.

Dissertation approval. Implementation of the received act based on the results of dissertation research in such organizations as LLP "Verigram" and LLP "Smart-edu.kz". "Verigram" LLP creates complex solutions in the field of recognition and verification of documents, persons, objects, as well as implements OCR and biometric technologies to improve the quality of customer service and fraud protection. LLP "Smart-edu.kz", in turn, presents educational courses designed for professional development and training of adults in various fields and professions, for example, such as computer graphics, Web-programming, etc. d. In these companies, the software product was tested for research purposes. The results of the work done were reported at the following conferences:

1. Uskenbayeva R.K., Mukhanov S.B. Contour analysis of external images, ACM International Conference Proceeding Series, 3410811, 2020.

2. Mukhanov S.B., Uskenbayeva R.K. Pattern Recognition Using Effective Algorithms and Methods of Computer Vision Library, Advances in Intelligent Systems and Computing, 2020.

3. Mukhanov S.B., Tursunov S.A., Izteleuov N.E., Tazabekov A. (2019) data science and machine learning "Changing Kazakhstan Society Using Smart Technologies".

4. Aitulen A.D., Mukhanov S.B., Khassenova G.I. (2019) data science and machine learning "Face Recognition Through Various Facial Expressions".

5. Slyamkhan S.M., Yembergenov A.A., Bordousov N.S., Mukhanov S.B. (2019) data science and machine learning "Game Application with Machine Learning Elements".

Communication with state programs. The review article of the dissertation work was published in the Materials of the World Congress on Global Optimization: 6th World Congress on Global Optimization, WCGO 2019 (Metz, France) within the framework of the implementation of the program-targeted financing project (IRN #BR05236517). The article with obtained results was published in Eastern-European Journal of Enterprise Technologies, 5 (2-113), pp. 44-54 (percentile 34) within the framework of the implementation of the grant financing project (IRN #AP08053034). The tasks set in this dissertation have high practical significance and are directly related to the processes of introducing digital technologies into production. Digitalization issues are actively discussed and receive special attention in the speeches of the President of the Republic of Kazakhstan Tokaeva K.K. and in strategic documents of the government, such as "Strategy "Kazakhstan-2050"" and "State program "Digital Kazakhstan".

Scientific publication.

1. Mukhanov S.B., Tursunov S.A., Izteleuov N.E., Tazabekov A. (2019) DATA SCIENCE AND MACHINE LEARNING "Changing Kazakhstan Society Using Smart Technologies".

2. Aitulen A.D., Mukhanov S.B., Khassenova G.I. (2019) DATA SCIENCE AND MACHINE LEARNING "Face Recognition Through Various Facial Expressions".

3. Slyamkhan S.M., Yembergenov A.A., Bordousov N.S., Mukhanov S.B. (2019) DATA SCIENCE AND MACHINE LEARNING "Game Application with Machine Learning Elements".

4. Aitulen A.D., Mukhanov S.B., (2019) "Obratobotka, Identification and Recognition of Persons by the Viola-Jones Method" - "Vestnik Kaznitu", No. 6.

5. Uskenbayeva R.K., Mukhanov S.B. Contour analysis of external images, ACM International Conference Proceeding Series, 3410811, 2020.

6. Mukhanov S.B., Uskenbayeva R.K. Pattern Recognition with Using Effective Algorithms and Methods of Computer Vision Library, Advances in Intelligent Systems and Computing, 2020, (Indexed in Scopus percentile - "28").

7. Kenshimov, C., Mukhanov, S., Merembayev, T., Yedilkhan, D. A Comparison Of Convolutional Neural Networks For Kazakh Sign Language Recognition (2021) Eastern-European Journal of Enterprise Technologies, 5 (2-113), pp. 44-54. (Indexed in the Scopus database, the percentile is "34").

8. Mukhanov S.B.*, Aldanazar A.A., Uatbayeva A.M., Alimbekov A.Ye., Marat G.S. COMPETITIVE LEARNING IN NEURAL NETWORKS, International Journal of Information and Communication Technologies, Vol.1, Issue 3, September, 2020 p.70.

9. Mukhanov S.B.*, Alimbekov A.Ye., Marat G.S., Uatbayeva A.M., Aldanazar A.A. AUTOMATION OF STAFF RECRUITMENT AND ASSESSMENT, International Journal of Information and Communication Technologies, Vol.1, Issue 3, September 2020, p.117.

10. S.B. Mukhanov, A. S. Lee, D. B. JEKSENOV, D. D. EVDOKIMOV, E. N. AMYRGALIEV, N. K. KALZHIGITOV, Sh. KENSHIMOV. Comparative analysis of

neural network models for methods of hand gesture recognition Bulletin NIA RK No. 2 (88) - 2023, Information and communication technologies.

11. Samat Mukhanov, Raissa Uskenbayeva, Young Im Cho, Kabyl Dauren, Les Nurzhan, Maqsat Amangeldi GESTURE RECOGNITION OF MACHINE LEARNING AND CONVOLUTIONAL NEURAL NETWORK METHODS FOR KAZAKH SIGN LANGUAGE. Vestnik Scientific Journal of Astana IT University, VOLUME 15, SEPTEMBER 2023.

Dissertation structure and volume. Dissertation consists of introduction, 4 main chapters, conclusion, list of references and appendices.

In the introduction of this rationale, the relevance of the research topic of the dissertation work. The goal, object, subject, methods and tasks of research work are set and formulated. The results of the experiments are described, the results of the studies obtained, their scientific novelty, practical significance and approval of the results of the dissertation research are shown.

The first chapter of the dissertation describes the theory of pattern recognition for task classification. Image recognition systems, environment and scope of application of recognition systems and requirements for development and improvement of these systems are considered. The presented tasks are car license plate recognition, face recognition and gesture recognition. Illuminated area of computer vision in image recognition, namely hand gestures.

In the second chapter, the general concepts of sign language and various international sign languages, as well as the dactyl alphabet of sign language are described. The Kazakh sign language, consisting of 42 (forty-two) letters in the format of images, is enlightened and presented. Theoretically described construction of hand gestures based on vector model in three-dimensional Euler space. Mathematically presented construction model of gestures in the form of equations in Euclidean space. The description of marking the key points and finding the tips of the fingers by contouring the palm, as well as the method of building the skeleton of the hand.

The third chapter of the dissertation contains the application of algorithms/methods of gesture recognition. The applied and described task classification is based on machine learning using machine support vectors, recurrent neural networks based on sequences, convolutional neural networks, and also deep learning. Applied architecture of neural networks for recognition of images, namely hand gestures. An important part of the structure of the neural network, in which pictures are used as objects for learning, matrix filters, convolution parameters and composition of filters, is highlighted. Mathematically described (calculated by formulas) and proven (calculations of matrix products of vectors for each layer of parameters - weights and displacements and applications of complex differential equations) the importance of using the learning algorithm (backpropagation), the method of reverse propagation of errors for the calculation of the gradient (gradient descent) and the need to use the activation function to minimize the loss function.

The fourth chapter describes the experiment of the research work, namely how the Kazakh sign alphabet is recognized. Obtained results using metrics for testing deep learning models. The accuracy of recognition of these models is proven on the basis of metric accuracy (precision), completeness (recall), F1-score (measure) and support

(support) for each class, as well as general accuracy (accuracy) and average scores (average). The constructed hybrid architectural model of the neural network with the use of recurrent and convolutional neural network layers was tested. Software that recognizes gestures in real time has been developed.

In the conclusions of each chapter, the main results of the work, the conclusion of the thesis and future steps of research are presented.