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VOICE RECOGNITION, TEXT CORRECTION FROM INDONESIAN SPEAKING BASED ON NLP AND TEXT MINING

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Abstract: *Today information technologies play an increasingly significant role in society. The technology development has already reached such a level that large corporations are beginning to use systems not only for processing information, but also for forecasting certain processes in society, nature, economy and other spheres of human life. One of these ways of processing information without using human resources is neural networks. The scientific novelty is determined by the fact that the article explores the symbolic analysis of text using a neural network. Recognition of written characters using a neural network could be useful for psychological studies of the relationship between a person's psychological state and his handwriting. As can be found out in a person's handwriting, the size of a slope, the direction of the letters, the pressure on a pen and the nature of lettering itself are important. If to combine a neural network for recognising written signs and a database of handwriting of many people, interesting statistics can be seen and the attempt to find connection between handwriting and character can be made. The practical significance of the research is determined by the fact that the research results can be used by specialists in different fields. The main problem in these cases is an optimised written character recognition algorithm that can correctly and quickly recognise written characters. Based on this, the object of research is the algorithm for recognising written characters, and the subject of research is the neural network itself.*

Keywords: neural network, text analysis, intelligent, information technology.

Neural networks are finding an increasing number of areas where they can be applied. They are used to translate texts from one language to another as a Google Translate service, for automatic face recognition as in the social network Facebook, where the network itself marks people in photos. Also, neural networks are used in more complex situations. These situations include forecasting any social, economic or natural processes. For example, forecasting the exchange rate used to take a lot of money, human resources and time, but now the neural network only needs technical support for work, and it does its work many times faster than a person[1]. In recent years, the power of servers and computers has grown to such an extent that they can easily process millions of megabytes of information in a few seconds[2]. This helped neural networks gain significant popularity in large corporations. Previously, usual human resources were used instead, but now all these processes are done automatically. Students have a situation when they need to transfer the lecture

[1] A. Ali, M. Pickering, "A hybrid deep neural network for Urdu text recognition in natural images", in *2019 IEEE 4th International Conference on Image, Vision and Computing, ICIVC 2019,* Institute of Electrical and Electronics Engineers, Piscataway, 2019, p. 321-325.
[2] D. Aizstrauta, A. Celmina, E. Ginters, R. Mazza, "Validation of integrated acceptance and sustainability assessment methodology", in *Procedia Computer Science*, 2013, vol. 26, p. 33-40.

notes to other colleagues in a group to study the educational material before an exam. Students forward information by photographing each page of the notebook and sending it through social media to their colleagues, or simply transferring the notebook so that other students can rewrite the outline. Unfortunately, in these cases, other students find it difficult to recognise the handwriting of a person who wrote the notes[3].

Tourists have a situation when, not knowing a language of a country they are visiting, they cannot recognise navigation texts in transport, on streets and in other places where English is not used due to the unpopularity of a country for tourists, but this information is useful and important for the visitors of a foreign country[4]. This may especially apply to countries of the world where hieroglyphs are used instead of Latin or Cyrillic letters, for example, as in China or Japan. For such a situation, it would be great to photograph the inscription and send it to the service, where this inscription would be recognised, translated into a human-readable form, and problems in staying in a foreign country would be solved[5].

For government services, the element of document flow and, in general, the documentation system is very important. Any action is usually indicated by a document that grants the right to a particular person to work on the issues that he must solve. One of the stages of this work is writing a statement[6]. Applications are often in writing, and in order to translate an application into electronic form, usually state institutions simply keep the specified application with them, and it has a chance to get lost. After that, the government agency still needs to prove that the application was written[7]. To solve this problem, the

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[3] A.V. Pyataeva, S.A. Genza, "Artificial neural network technology for text recognition", in *CEUR Workshop Proceedings*, 2019, vol. 2534, p. 248-252; Y.S. Tokatligil, A.Z., Saliyeva, F.N. Zhumabekova, "Psychological aspect of the training process of preschool education students", in *Quality and Quantity*, 2021, vol. 1, no. 1, p. 1-12.

[4] A. Acar, "On the question of what translation translates: Translation in light of skepticism", in *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 2021, vol. 13, no. 1, p. 1-11; A.N. Muratova, S. Mazhitayeva, B.Zh. Sarybayeva, A. Kelmaganbetova, Z. Kulibekova, "Non-verbal signs and secret communication as universal signs of intercultural communication", in *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 2021, vol. 13, no. 1, p. 1-9.

[5] A. Bezrukov, O. Bohovyk, "Creating communicative space and textual reality via emotiogenic means in fictional discourse", in *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 2021, vol. 13, no. 1, p. 1-14; O. Romaniuk, "Effective self-disclosure within the masculine romantic discourse: variable communicative moves", in *Analele Universitatii din Craiova - Seria Stiinte Filologice, Lingvistica*, 2019, vol. 41, no. 1-2, p. 139-156.

[6] M. Agarwal, B. Kaushik, "Text recognition from image using artificial neural network and genetic algorithm", in *Proceedings of the 2015 International Conference on Green Computing and Internet of Things, ICGCIoT 2015*, Institute of Electrical and Electronics Engineers, Piscataway, 2016, p. 1610-1617.

[7] W. Lu, H. Sun, J. Chu, X. Huang, J. Yu, "A novel approach for video text detection and recognition based on a corner response feature map and transferred deep convolutional neural network", in *IEEE Access*, 2018, vol. 6, p. 40198-40211.

work of a neural network can be useful, which translates the text of the application into electronic form and allows solving another issue of bureaucracy and make the transparent workflow even closer to reality[8].

The well-known world company Google has developed the Google Translate application, which helps a person translate words and sentences from one language to another[9]. Prior to this application, a character recognition function was added a few years ago and its one-time translation from one language to another. The latest research and publications can be seen on the official blog of the Google-AI company Google Blog, where the latest articles are devoted to music recognition or what is captured in photographs. Another fairly well-known company Adobe has developed a computer application, Adobe Acrobat DC, in which there is a function for recognising written characters on paper in electronic form. Adobe is trying to pay considerable attention to this function because of its prospects, and in the specified application it is available only after purchase. All information about the development of this technology in the company can be found through its blog and a person can draw his own conclusions about the development of text recognition technology at this time.

Materials and methods

The text recognition market does not stand still, and this can be observed on the example of a company ABBYY. The company works with such global companies as Fujitsu, Panasonic and Xerox. One of the main applications the company works with is ABBYY FineReader, which is especially good for OCR[10]. ABBYY is trying not only to develop applications but also to work with its audience through speaking at conferences, writing

[8] B. Zhu, M. Nakagawa, "Segmentation of on-line handwritten Japanese text of arbitrary line direction by a neural network for improving text recognition", in *Proceedings of the International Conference on Document Analysis and Recognition*, 2005, vol. 1, p. 157–161; R. Ramya, S. Rukmini, "Literature in new media: A comparative study of literary affordances of lance Olsen's "10:01" in traditional and digital medium", in *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 2021, vol. 13, no. 2, p. 1-13; I.E. Suleimenov, O.A. Gabrielyan, A.S. Bakirov, Y.S. Vitulyova, "Dialectical understanding of information in the context of the artificial intelligence problems", in *IOP Conference Series: Materials Science and Engineering*, 2019, vol. 630, no. 1, article number 012007.

[9] M.M. Altuwaijri, M.A. Bayoumi, "Arabic text recognition using neural networks", in *Proceedings – IEEE International Symposium on Circuits and Systems*, 1994, vol. 6, p. 415-418; C. Pataca, "The Internet of things: Typologies, protocols and applications", in *Law, State and Telecommunications Review*, vol. 13, no. 2, p. 198-220.; R. Escobar-Briones, N.M. Conde-Menchaca, "Competition and its impact on investment in telecommunications networks in a digital environment", in *Revista De Direito, Estado e Telecomunicacoes*, 2020, vol. 12, no. 2, p. 64-90.

[10] Y.-C. Wu, F. Yin, C.-L. Liu, "Improving handwritten Chinese text recognition using neural network language models and convolutional neural network shape models", in *Pattern Recognition*, 2017, vol. 65, p. 251-264.

articles on developing its FineReader application and holding its events to a large audience[11].

The latest example of the use of technology for recognition of written signs can be seen in a world-famous company – Microsoft. For its Microsoft Office application, a function was developed to translate an image with text into an electronic form. Unfortunately, the company does not pay enough attention to the development of this technology and tries to focus on other things that are more important for the company. Knowing the specifics of a corporation's work, if it lags far behind its competitors, it will be able to quickly catch up with competitors because of the large workforce that works in the company.

In general, it can be seen that the technology of recognition of written characters is rapidly developing in the world market and does not stand still. This technology is used not only for the future because of its free use, but already has a commercial benefit for its developers. It will be interesting to imagine how this technology can work in conjunction with other neural networks and what can come of this for all users of this system. Perhaps it will be possible to not only work with this technology through photographs, but in real time, when glasses will be created, as in Google – Google Glasses[12].

Particular attention should be paid to the analysis of types of neural networks and the use of different types of networks in solving the problem of recognition of written characters. After choosing the type of neural network that will be used for the specified task, it is necessary to analyse the algorithm of the specified type of neural network and make its optimisation to speed up epycharacter recognition[13]. A separate stage should be given to the stage of training the neural network. It is necessary to conduct its training and analyse the efficiency of work before and after training and draw conclusions regarding the system operation with the coverage of the statistics of the correct character recognition[14].

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[11] Z. Lei, S. Zhao, H. Song, J. Shen, "Scene text recognition using residual convolutional recurrent neural network", in *Machine Vision and Applications*, 2018, vol. 29, issue 5, p. 861-871.

[12] H. Chel, A. Majumder, D. Nandi, "Scaled conjugate gradient algorithm in neural network-based approach for handwritten text recognition", in *Communications in Computer and Information Science, 204 CCIS*, 2011, p. 196-210; A.K. Dwivedi, A.K. Sharma, "EE-leach: Energy enhancement in leach to improve network lifetime of homogeneous wireless sensor network", in *Revista De Direito, Estado e Telecomunicacoes*, 2020, vol. 12, no. 1, p. 205-224.

[13] A.S. Bakirov, I.E. Suleimenov, "On the possibility of implementing artificial intelligence systems based on error-correcting code algorithms", in *Journal of Theoretical and Applied Information Technology*, 2021, vol. 99, no. 1, p. 83-99; A. Akanova, N. Ospanova, Y. Kukharenko, G. Abildinova, "Development of the algorithm of keyword search in the Kazakh language text corpus", in *Eastern-European Journal of Enterprise Technologies*, 2019, vol. 5, no. 2-101, p. 26-32.

[14] M. Yousef, K.F. Hussain, U.S. Mohammed, "Accurate, data-efficient, unconstrained text recognition with convolutional neural networks", in *Pattern Recognition*, 2020, vol. 108, article number 107482.

In addition, it is necessary to analyse the operation of the network with incorrect input data[15]. For example, if the text in the image is not clearly indicated or the characters are written quite crookedly due to the person's poor handwriting[16]. It is necessary to find ways to solve the question posed and draw conclusions regarding the very possibility of attempting to recognise characters through incorrect input data[17]. In general, it is needed to indicate what is the prospect of the neural network in the task of recognising written text[18]. Additionally, it is possible to reveal even more the question of the purpose of the neural network as a whole as a system that has a perspective in the near future and how a person can use this technology in his daily life[19].

Results and discussion

Characteristics of the neural network and its types

The use of a neural network today is very popular among large corporations and such a network can be developed not only using human resources that are calculated by hundreds or thousands of people[20]. Today, enough information has been provided about neural networks that can help reveal all the questions regarding it, and they are analysed below[21]. The definition of a neural network is quite simple – it is a computation system that is similar in analogy to a biological neural network. It should be noted that a neural network itself is considered an algorithm, but rather is a mixture of various machine learning algorithms that, working together, process input data

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[15] B. Su, X. Zhang, S. Lu, C.L. Tan, "Segmented handwritten text recognition with recurrent neural network classifiers", in *Proceedings of the International Conference on Document Analysis and Recognition*, 2015, p. 386-390.

[16] B. Shi, X. Bai, C. Yao, "An end-to-end trainable neural network for image-based sequence recognition and its application to scene text recognition", in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2017, vol. 39, no. 11, p. 2298-2304.

[17] H. Zhoushao, "Emotion recognition simulation of Japanese text based on FPGA and neural network", in *Microprocessors and Microsystems*, 2020. Available at https://www.sciencedirect.com/science/article/abs/pii/S014193312030541X?via%3Dihub

[18] H. He, J. Li, "Attention-based deep neural network and its application to scene text recognition", in *IEEE 11th International Conference on Communication Software and Networks*, 2019, p. 672-677.

[19] H. Hattori, "Text-independent speaker recognition using neural networks", in *IEEE International Conference on Acoustics, Speech and Signal Processing – Proceedings*, 1992, vol. 2, p. 153-156.

[20] U. Hayat, M. Aatif, O. Zeeshan, I. Siddiqi, "Ligature recognition in Urdu caption text using deep convolutional neural networks", in *2018 14th International Conference on Emerging Technologies*, 2018, p. 1-6.

[21] G. Zhong, G. Yue, "Attention recurrent neural networks for image-based sequence text recognition", in *Lecture Notes in Computer Science*, 2020, vol. 12046, p. 793-806.

and output the result of their work[22]. The structure of a neural network reflects a set of nodes that are connected to each other – this structure is called a neuron. Each node is used to transmit a signal from one neuron to another[23]. Each neuron and node have a weight that is adjusted during training[24]. Weight is used to determine which neurons and nodes to use in information processing. Neurons are part of the layers. Each layer performs a different kind of information processing[25].

Feedforward neural network. This neural network is one of the simplest forms of neural networks where information moves in one direction. Information enters through input nodes and exits through output nodes. The specified type of neural network can have a hidden layer. The feed-forward network may find its purpose in the development of computer vision technology and speech recognition.

Radial basis function. The specified type of neural network should, by its nature, take into account the distance of a point to the centre. The network has two layers: the first layer, where the features are combined with the radial basis function; the second layer, where the result of these summations goes to the layer, where the main calculations go and corrects the result in one direction or another. The model depends on the maximum coverage or radius of a circle when classifying points into different categories. If a point is within or around it, then the probability that a new point will begin to classify in that class is high. There can be a transition when moving from one region to another, and this can be controlled by an additional function. This neural network has been applied in renewable energy systems. Power systems have grown in size and complexity. Both factors increase the risk of a power outage. After a power outage, it is necessary to restore power as quickly and reliably as possible.

Self-organising Kohonen map. The goal of the Kohonen map is to introduce vectors of arbitrary dimensions to a discrete map consisting of neurons. For the Kohonen self-organising map to work properly, it needs to

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[22] D. Oprea, "Big Questions on big data", in *Revista de Cercetare si Interventie Sociala*, 2016, vol. 55, p. 112-126; H. El Bahi, A. Zatni, "Text recognition in document images obtained by a smartphone based on deep convolutional and recurrent neural network", in *Multimedia Tools and Applications*, 2019, vol. 78, issue 18, p. 26453-26481; R. Baembitov, T. Dokic, M. Kezunovic, Y. Hu, Z. Obradovic, "Fast extraction and characterization of fundamental frequency events from a large PMU dataset using big data analytics", in *Proceedings of the Annual Hawaii International Conference on System Sciences*, 2021, vol. 2020, p. 3195-3204.

[23] S.F. Rashid, F. Shafait, T.M. Breuel, "Scanning neural network for text line recognition", in *Proceedings – 10th IAPR International Workshop on Document Analysis Systems*, 2012, p. 105-109; A. Aizstrauts, E. Ginters, M. Baltruks, M. Gusev, "Architecture for distributed simulation environment", in *Procedia Computer Science*, 2015, vol. 43, no. C, p. 18-25.

[24] B. Flores, T. Tran, "Use of neural networks in the formation of a high-quality smoothed audio signal", in *Scientific Herald of Uzhhorod University. Series "Physics"*, 2021, vol. 49, p. 35-42.

[25] Z. Meng, S. Tian, L. Yu, "Regional bullying text recognition based on two-branch parallel neural networks", in *Automatic Control and Computer Sciences*, 2020, vol. 54, issue 4, p. 323-334.

be trained so that it can create its own work structure. This type of neural network consists of one or two dimensions. During training, the neuron location map remains constant, but the scales differ depending on the value. The self-organisation process has several stages: in the first phase, each neuron value is initialised with a small weight and an input vector; in the second step, the neuron closest to the point is the "winning neuron" and the neurons connected to the winning neuron also move to a point similar to the graph below. The distance between the point and the neurons is calculated by the Euclidean distance, the neuron with the smallest distance wins. Through iterations, all points are clustered and each neuron represents each kind of cluster. The self-organising Kohonen map is used for pattern recognition. Its use can be found in medical analysis to group data into different categories.

Recurrent neural network. A recurrent neural network works by storing the output of a layer and feeding it back to the input to help predict the outcome of a layer. Here the first layer is formed similar to the original neural network with the product of the sum of weights and functions. The process of the recurrent neural network itself begins to work after calculating the first layer. This means that from one stage to the next, each neuron will remember some of the information it had in the previous step. This behaviour shows that each neuron acts as a memory cell in the execution of computations. In this process, it is necessary to let the neural network work on propagation from the front and remember what information is needed for further use. If the prediction is wrong during the process, learning rate or error correction is used to make small adjustments to gradually work towards correct prediction during backpropagation. An application of a recurrent neural network can be found in text-to-speech transformation (TTS) models.

Convolutional neural network. A patterned neural network is similar to feed-forward neural networks where neurons have weights and nodes[26]. This network is used in signal and image recognition processes. Below the work of a neural network can be seen, where the input data is processed in batch, like a filter. This will help the network remember the images piece by piece and can calculate operations. These calculations involve converting the image from RGB or HSI to grayscale. After that, changes in the pixel value will help to reveal the edges of the image and it can be divided into different categories.

Modular neural network. A modular neural network contains a set of different networks that work independently of each other and contribute to the correct final result of the network. Each neural network has many inputs that are unique compared to other networks that build and execute subtasks. These networks do not communicate or signal to each other when performing tasks. The advantage of a modular neural network is that it breaks down a large

[26] I.I. Bondar, V.V. Suran, "Use of convolutional neural network", in *Scientific Herald of Uzhhorod University. Series "Physics"*, 2021, vol. 49, p. 43-47.

computational process into smaller components, which reduces the complexity of the computation[27]. This breakdown helps to reduce the number of connections and conflicts between these networks with each other, which, in turn, increases the speed of computation. However, the processing time will depend on the number of neurons and their participation in calculating the results. For the system to work, which will perform the recognition of written characters, it is needed to use a convolutional neural network – an architectural system that was created just to identify objects in an image and can be used in a situation of recognising written characters.

Patterned neural networks are usually associated with computer vision, and their history goes back to the 1980s, when Japanese Kunihiko Fukushima proposed a neural network architecture that was inspired by the cat's visual recognition system. Since then, recognition methods and algorithms have begun to gain even higher development momentum. It got to the point that in 2005 an algorithm was developed, thanks to which a neural network can use not only processor power, but also the power of a video card to calculate work on an image. Also, in the last decade, the open world database Modified National Institute of Standards and Technology (MNIST) was developed, which can help the neural network learn even faster thanks to the preserved information of all letters and numbers, in order to quickly teach the neural network to recognise text in an image. While the network is running, an image is taken, processed through a series of convolutional, nonlinear, merge and fully connected layers, and the result is generated. The result can be the class or the likelihood of classes that best describe the image.

The first layer in a convolutional neural network is convolutional. The input is an image – this is a 32x32x3 matrix with pixel values. The convolutional layer works thanks to the filter. This filter (also called a neuron or a nucleus) can cover an area of the image, for example 5x5 pixels, and it will move across all areas of the image. The areas, which the filter processes, are called the receptive field (or the field of perception). That is, the specified filter is a matrix (it is also called a weight matrix or a matrix of parameters). It should be noted that the depth of the filter should be the same as the depth of an image and the size of this filter will be – 5x5x3. Usually, the filter takes a position in the image from the upper left corner. Since the filter is convolutional, that is, it moves through the input image, it multiplies the filter value by the input pixel values of the image (elementwise multiplication). All these multiplications are summed up, in this example it will be 75 multiplications). The result is one number. Now it is needed to complete this process in each position. Each unique position of the input image outputs a

[27] I. Suleimenov, A. Bakirov, I. Moldakhan, "Formalization of ternary logic for application to digital signal processing", in *Advances in Intelligent Systems and Computing*, 2021, vol. 1259 AISC, p. 26-35.

number. After passing the filter for all positions, a 28x28x1 matrix appears, which is called the activation function or feature map. The 28x28 matrix arises because there are 784 different positions that can pass through the 5x5 filter of a 32x32 image. These 784 numbers are converted to a 28x28 matrix.

Each filter can be thought of as a property identifier. The filter has a pixel structure in which the numerical values are higher along the region that defines the shape of the curve. When there is a filter in the upper left corner of the input image, it multiplies the filter values by the pixel values of that area. If there is a shape in the input image that is similar in general to a curve that represents a filter and all the multiplied values are added together, then the result will be a large value. It is worth keeping in mind that the result of a convolutional network is a property map. In the simplest case, with only one convolution filter (and if that filter is a curve detector), the property map will show the area where the curve is most likely to be detected.

The next stage of the algorithm is processing the result of the filters – a map of properties. Filters that represent higher-level properties will work at this stage. The types of these properties can be semi-rings (a combination of a straight border with a bend) or squares (a combination of several straight edges). The more convolutional layers an image passes and the further it travels through the network; the more complex characteristics are displayed on activation maps. At the end of the network, there may be a filter that is activated when there are unfamiliar characters, objects, and the like.

The final stage is attaching fully connected layers to the end of the network. This layer takes the input and outputs an N-spacious vector, where N is the number of classes the program chooses to use. For each class, the probability of its coincidence with the result of information processing is established. The way a fully connected layer works is by accessing the output of the previous layer and defining properties that are more related to a specific class. A fully connected layer looks at the fact that the high-level functions are strongly associated with a certain class and have a certain weight, so when the multiplication of the weight with the previous layer is calculated, the correct probability for the different classes is displayed.

The main stage of a neural network is its training. As is known, a neural network cannot work correctly the first time and it needs to be taught to work on errors[28]. If to talk about the process of recognising written characters, then each person has his own handwriting, in which it can be difficult to recognise which letters are written or a text can be written can be so compressed that the

[28] D. Aizstrauta, E. Ginters, "Integrated acceptance and sustainability assessment model transformations into executable system dynamics model", in *Procedia Computer Science*, 2015, vol. 77, p. 92-97.

neural network can recognise individual words as one word[29]. To train a neural network, a person should write the letters of the alphabet several times so that the neural network can adapt to the person's handwriting. It is also possible to use the MNIST database, which stores human-written letters and numbers, and this can help speed up the learning process of the system. The MNIST database stores over 60000 training images and 10000 test images. With the help of this base, scientists tried to minimise the number of errors in training a neural network. Thanks to them, it was possible to reduce the number of errors to 0.23%, and the indicated result is almost similar to the recognition of symbols by human vision.

A special stage should be the processing of text with errors, where the neural network must identify these errors, correct them and process them correctly[30]. For this, a dictionary must be connected to the neural network and the grammar of each language must be connected to this rule. For example, Google companies have been trying for 10 years to make their translator work correctly, but the result is still not the best and the system sometimes cannot pronounce some words. For a neural network to work with false input data, the number of iterations of the neural network must reach 1000 or more times. The more iterations, the better the neural network will do its job.

Features of software architecture development

For the written character recognition system to work properly, attention must be paid to the design of the software architecture. After that, it should identify the algorithm of the application and what situations need to be thought out in advance before developing the application. For the development of software architecture, the Model-View-Controller (MVC) model is used (Figure 1). With the help of controllers, it is possible to process incoming information. With the help of models, information for further training of the neural network is stored. With the help of the interface, the original information in a user-friendly appearance is displayed correctly[31].

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[29] P. Mohanty, "Orality, literacy and translation", in *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 2021, vol. 13, no. 2, p. 1-10; O.V. Hurko, "Compiled name as a type of nomination graphic design terminology vocabulary", in *Journal of Language and Linguistic Studies*, 2021, vol. 17, no. Special Issue 2, p. 1253-1263.

[30] S. Mukherjee, D.A. Mohanty, "Role of code-switching and code-mixing in indigenous communicative contexts: A study of the god of small things", in *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 2020, vol. 12, no. 2, p. 1-11.

[31] O.V. Kozachenko, "Mathematical modeling of the stability of the system", in *Machinery and Energetics*, 2021, vol. 12, no. 4, p. 61-66.

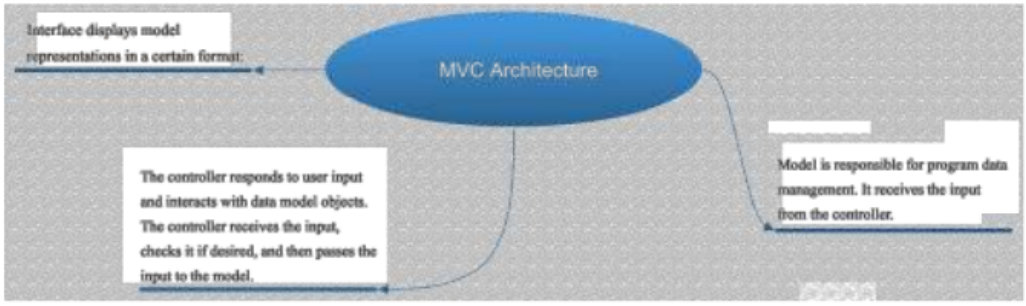

Figure 1: Interoperability in MVC architecture

The split MVC model provides the versatility of both parts individually and the system as a whole. Isolating the page mark-up and isolating the data model from the entire process provides high product flexibility. Without MVC, it's hard to achieve this level of versatility. At the same time, MVC technology has its drawback – the complexity of development. The implementation of such a project will take much longer than the implementation of a project without MVC. If to talk about the model of the system, then it will look like this:

1. Image processing and text recognition in general. This stage is needed to identify the boundaries of a text. This procedure is done by working with image filters to identify where a text is, and where the usual "noise" objects are depicted (pen, pencil, specks in the image, etc.).

2. Processing each individual word by defining indents between words. The main problem at this stage can be confused letters in a word with a separate word. To solve this problem, the neural network must learn to adapt to the handwriting of an individual.

3. Identifying individual letters in a word and recognising what block letters they look like. The complexity of this stage will consist only in the handwriting of each person and the identification of the main features of each individual letter in a word.

Testing the recognition of each individual word is done by detecting colour change and setting the weight factor of a text so that the special features of each letter can be identified[32]. For example, for the letter "B" the main signs are 2 circles. To find these 2 circles, first it is needed to find the edges of each letter. For example, in the picture it can be seen where there is an inscription with a pen, and were not. Secondly, it is needed to build a symbol using a line. The work of detecting and recognising each letter is not so difficult, but there are times when it is necessary to think about how some letters are distinguished for a neural network. Unfortunately, such moments will arise during the operation of the system quite often, and the stage of identifying each individual

[32] H.V. Tovkanec, V.V. Szilágyi, "Language comprehension and text creation tasks", in *Scientific Bulletin of Mukachevo State University. Series "Pedagogy and Psychology"*, 2021, no. 1, p. 188-191.

word in a sentence comes to the rescue, which makes it possible to select an entire area of a word and see if the neural network accidentally missed any inscription.

An image of a letter is taken from a photograph taken for processing. This image is divided into uniform square blocks, which are then analysed. Each block is multiplied by a matrix of weights, and itself the result is added up. In turn, these blocks are subdivided into smaller blocks and certain calculations are made. In turn, the result will be displayed as a vector, which by its characteristics can be associated with the required letter. It's no secret that one of the main elements of a neural network is a programming language in which a system is written. There are times when a particular language cannot work correctly and easily with a large amount of data or does not support certain algorithms for faster system operation. Below, programming languages will be indicated as suitable for use with neural networks, the pros and cons of the language and which libraries exist to solve a particular issue.

The world IT company Python Software Foundation has created its own programming language Python and a library that can facilitate the development of a network using ready-made methods that have already calculated possible errors when working with input data. In general, the Python programming language is quite popular in processing large amounts of data and the operation of neural networks. Also, this language is quite easy to learn and requires a low level of knowledge, which will save time in familiarising with the work of neural network algorithms. If to talk about the shortcomings of the specified programming language, then it is quite slow compared to such programming languages as C#, Java, and even more so C++. Also, the specified language cannot work with computer memory as efficiently as C++, since working with memory in Python is done automatically without manual control from the system developer. Another disadvantage is work with multiple processor cores, since, unlike the C++ programming language, work on multiple threads occurs automatically without the programmer's intervention in the program code.

Almost all neural networks in the Python programming language use the default NumPy library, which allows to quickly and efficiently work with matrices, tables of numbers in different formats, numerical data, and also carry out a large number of typical operations that are needed in the process of a neural network. It can be added that the libraries and the programming language have clear documentation that makes it easier to understand the work of algorithms, methods, and the like. Since working with matrices is key in recognising objects in an image, this library can be of great importance. To work with tabular data, the Pandas library can be used, which allows to quickly load data, prepare it for the required format of sending the work of the neural network algorithm. Using the library, time of writing program code can be saved and these functions are fitted in 20-30 lines. A special moment is that during the operation of these libraries, not only processor power, but also the

power of video cards can be used, which will save the time of the algorithm and increase its performance.

Also, to work with a neural network, Google has developed its own library, which is primarily intended for the Python language – TensorFlow. The specified library is open source and can be improved by third-party developers, which can help develop libraries even faster than if it were closed. Google uses this library at work, so it is currently relevant for all its other users. The work of such a system is observed in a special Google search function, where one image is uploaded and similar ones are found. Library functions can work in parallel using video cards and multi-core processors. To work with a neural network, the C# programming language can be used. For this language, Google has created its AForge library, which is designed for use by programmers and researchers in the field of artificial intelligence, namely in image processing, working with a neural network, genetic algorithms, learning machines, robots, and the like (Figure 2).

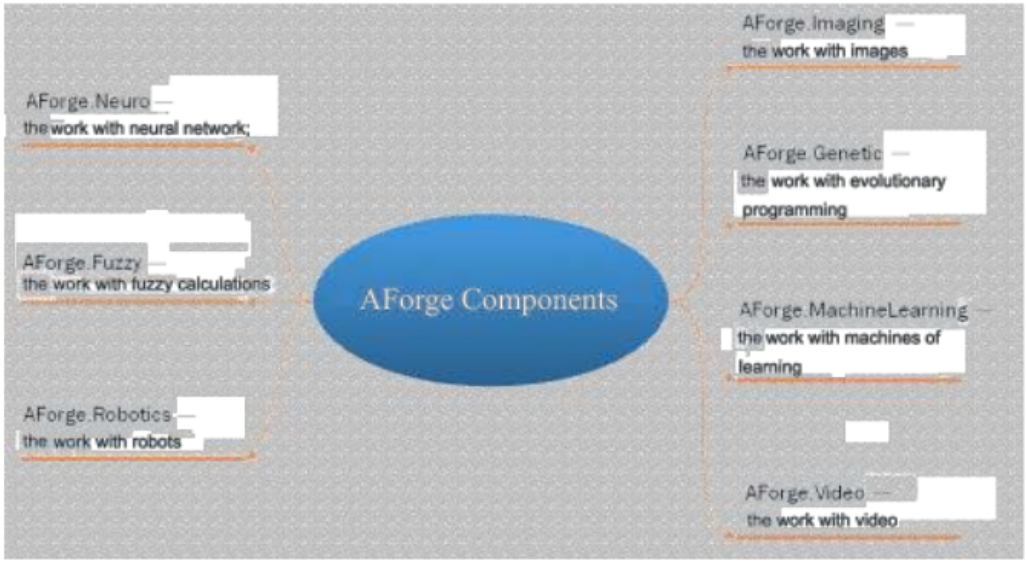

Figure 2: AForge components

This library is constantly developing and improving, which means that newer functionality will come to this library. The site and forum of the developers of this library contain information on the development of the library. Also, this library has examples of working with various data types, which allows evaluating the working functionality of the framework, and in this library, there is also documentation that can help better understand the algorithm of each function. Another library that can be used is the Cognitive Toolkit, which was developed by Microsoft specifically for working with neural networks. Unlike the AForge library, Microsoft has made it its goal to compete with popular neural network libraries such as TensorFlow. Unlike the

TensorFlow library, this library is faster, more accurate than its competitor. Unfortunately, the main drawback of the library is its documentation, which is not as well developed and understandable as the competitor's one.

If to talk about the programming language in general, then it is a direct competitor to Java and has been developing better lately. For example, the Java language has become so big that its expansion is slower, and C# is focusing on developing web applications that can already directly compete with Java in terms of multi-platform. Unfortunately, the main drawback is the commercial work of Microsoft with the audience, since to work in the specified language, it is needed to have paid Microsoft products, ranging from the operating system to the choice of a database or an application development environment. This makes the choice in the specified programming language more difficult, especially if there are other simpler analogues.

For one of the well-known programming languages, enough libraries have also been developed for working with neural networks. If to talk about these libraries, then Encog and JOONE can be specified. If to talk about JOONE, then this library is used rather as a basis for working with neural networks. In order to create an algorithm for recognising written characters, it will take a long time to create processing methods and, unlike other libraries, it does not have ready-made methods for this situation. If to talk about Encog, then this is another library that is used as a basis for working with neural networks. Unfortunately, the specified library also does not solve the issue of recognising written characters using ready-made algorithms and all the functionality must be written manually.

As can be seen, these libraries cannot solve in an easy way the issue of creating a neural network for recognising written characters. Still, it is needed to spend time on analysis, preparation, creation of manual processing methods, and it is not yet known how much time is needed to be spent on optimising the algorithm and correcting its errors. In defence of the specified programming language, it can be said that it works on all operating systems: Windows, Linux, Mac. The programming language itself has become a world classics of programming web applications or systems that have been in use for several decades. This is especially true in the financial sector, where banks and their systems are the main users of the Java programming language.

If to talk about the programming language C++, then it is suitable for all tasks. One of the main programming languages for any large company and there are well-known libraries. The advantages of this language include the ability to manually work with memory and computer cores, as well as the ability of programs written in C++ to run on all operating systems. Unfortunately, this language has one big drawback – its complexity of work and the difficulty of learning. To develop any application, it is required to spend a lot of time to understand how to work with computer memory and what pitfalls can be encountered in the development of any application. This

programming language has one of the popular libraries for working with neural networks – Caffe. This library was developed by a student from the USA Yangqing Jia, who developed it for his scientific dissertation and the library's algorithm was picked up by many programmers who are currently developing this library.

First of all, this library is used to work with a convolutional neural network, which is where the main focus is. To test the operation of a neural network, it is important to implement a convenient interface for a more convenient understanding of the information that has been processed and what will be displayed. The system interface will be developed using the programming languages HTML, CSS, JavaScript. The system will work by processing GET and POST requests. Front-end programming languages (HTML, CSS, JavaScript) are used in all websites. Currently HTML version 5 is used, which can help develop a web page with a dynamic and animated interface.

If to talk about CSS, then at present they use its version 3, which is standardised along with HTML 5 on all Internet browsers. If the HTML and CSS languages are standardised, then they should have convenient and informative documentation, and this is their main advantage when developing the interface of a web application. The JavaScript programming language at this time is developing at an ever-increasing pace due to the great popularity of the server-side programming language NodeJS. Currently JavaScript has version 18 and the version of this language is updated every year. In general, JavaScript has already reached such heights that most likely libraries have already been developed in this programming language for working with large amounts of data and for working with a neural network. Unfortunately, this speech was not originally created to work with such functionality and is primarily focused on developing the appearance of any web application and prescribes functions for sending requests to the server and receiving information from there.

If to talk about other alternatives to the development of the appearance system, then it would be possible to develop an application on a computer using Windows Presentation Foundation (WPF) technology, but this technology uses the C# programming language and has a not very easy architecture of work, because of which it may not be a good idea to develop an application on WPF, especially when the Python programming language was chosen.

Conclusions

Neural networks are a system that can help solve many issues that previously could only be solved by humans. These include cases of recognising objects in a picture or predicting the weather, exchange rates, social behaviour.

The use of a neural network on various computer systems and various software tools was analysed that will work when using a neural network to recognize written characters. Additionally, the model of the system for recognising written characters and ways to optimise the stages of the system's work with incorrect input data was analysed. The text recognition algorithm can be improved by increasing the number of tests of this system. An important part of the operation of such a system will be played by the optimisation of the algorithm for processing photos with text. The operation of a text recognition algorithm can have many areas where it has a chance to be used and extended to work with other networks. These are works on recognising the text of a language unfamiliar to a person and translating it into a familiar language, or sooner or later a system will be developed that describes a person's character through his handwriting.

In general, if neural networks have prospects of use in all spheres of human life. For example, a smart home project, where the system will adapt to human life and process input data such as time, temperature and humidity, human voice, etc., and the output will result in the correct operation of this system, which can make life easier.

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