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# Braille Character Recognition Based on Neural Networks

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***Abstract*—Braille is the most popular system used for interaction between visually-impaired and sighted people using tactile means. Optical Braille character recognition (OBCR) includes two main steps: Braille cells' recognition (image acquisition, preprocessing, Braille dots' recognition, Braille cells' recognition and segmentation) and Braille cells' transcription to corresponding natural language characters. System example has been created using image processing methods and artificial neural networks approach. These methods allow to achieve high speed and recognition accuracy level. System can adapt to factors like quality of input patterns and differences between them dynamically. In this paper, artificial neural network is developed to identify letter's images of Cyrillic alphabet in Braille representation system. Network will be trained and tested for identifying of scanned Cyrillic letters in Braille. Some of the letters are noised with some type of noise to simulate the real-world environment.**

***Keywords*—alphabet, artificial neural network, Braille, character, image processing, image recognition.***

## I. Introduction and Problem Statement

As stated by World Health Organization in 2017, there are an estimated 253 million people around the world live with vision impairment: 36 million of them are blind and 217 million have moderate to severe vision impairment [1]. These people still continue to contribute efficiently to the society nevertheless their disabilities. However, they face with challenging problem about expressing their contributions as they use different scripting language, which makes information transferring between them and the sighted people more difficult. Braille was founded by a French teacher, Louis Braille, in 1824. It represents binary tactile code system used by blind and visually impaired people instead of usual printed reading and writing methods, so they can feel raised dots with tips of their fingers on Braille page. The Braille script represents of cells itself; each of them contains of six raised dots arranged in three rows and two columns as shown in Figure 1. These six dots can be raised or flat according to corresponding Braille character. They are interpreted as series of symbols ranging between 0 and 63, so these dots are combined to give 26 = 64 different sets of combinations (including the empty Braille character "space"). Mappings (sets of numbers and symbols) are different between languages in Braille alphabets. For example, there are 3 types of characters encoding in English language's Braille alphabet: *Grade 1* is basic literacy-used with letter-by-letter transcription; *Grade 2* is complemented by abbreviations and contractions; *Grade 3* varies from basics with non-standardized personal short hands.

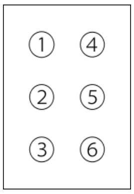


Fig. 1. Braille cell template

Braille paper's size can be also used not just for cell representing the character, but for word or even sentence. Therefore, Braille language consists of three grades: *Grade 1* – grade where each Braille cell represents a single language character and word is constructed of Braille cells' combinations. *Grade 2* is similar to Grade 1 but differs with some abbreviations and contractions. *Grade 3* is the most difficult Braille grade combining complex phrases and sentences. Figures 2, 3 show Grade 1 Braille alphabet for English and Ukrainian languages.

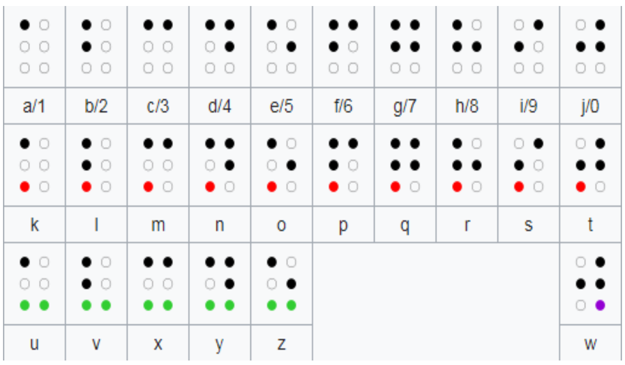


Fig. 2. Braille alphabet for English language

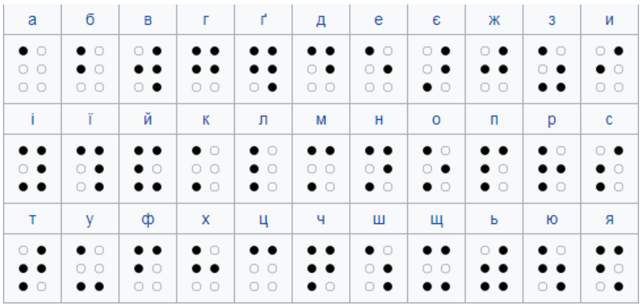


Fig. 3. Braille alphabet for Ukrainian language

This paper reviews Braille system, common techniques used to read and write it by blind people; contains a brief introduction of artificial neural networks; its structure, types of learning and Backpropagation algorithm; network's training, testing and results of these both processes.

Artificial neural network (ANN) will be designed to identify Cyrillic letters' images in this research. Some of them will be noised with some type of noise to simulate somehow the real-world environment. ANN will be trained and tested to be used for identifying them.

## II. Optical Braille Character's Recognition Methodology

Different sets of techniques used for optical Braille characters recognition system creating will be described in this section. Optical Braille characters recognition methodology is shown in Figure 4.

Optical Braille character recognition process in general can be split to next steps: 1) image acquisition; 2) image preprocessing; 3) image segmentation [2]; 4) Braille dot recognition [3]; 5) Braille cell translation [4].

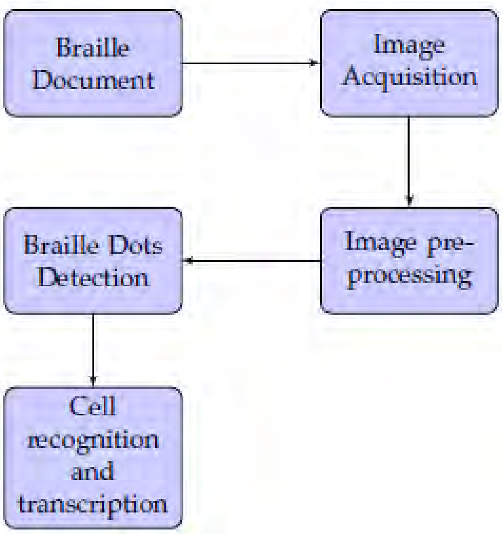


Fig. 4. General methodology

### A. *Image acquisition:*

Braille paper was captured using a scanner to take characters' images with a resolution of 41 pixels x 60 pixels. Capturing process' results are generated as JPEG-type image files and have black and white color scale.

### B. *Image processing:*

This method is used to prepare the picture for the next step, to make the process of Braille characters recognition easier. It includes image cropping, grayscaling, thresholding, erosion and dilation [5].

### C. *Image segmentation:*

Braille character segmentation's area correctness can improve recognition's accuracy level. Segmentation is done by making a small segment as many as 8 areas of segmentation, which consist of 2 columns and 3 rows. Value of pixels will be read from 8 small segmentations and equal to value between 0 (black) or 255 (white). So, each small segmentation area will get one data input. Therefore, process result will be 8 data. It will play a role of data source for artificial neural network process.

## III. Artificial Neural Networks

There was a huge growth of hybrid intelligent systems' successful using at different areas in recent years. Increased neural networks' using for pattern recognition, classification and optimization tasks has played the main contributing factor's role for the development of hybrid systems [6].

Artificial Neural Network (ANN) is computer technique designed to simulate the way of human brain to do different tasks. ANNs can do that by a lot of parallel distributed processing units – "nodes". These units are mathematical models called "neurons". They have ability to process and store information as same as biological neurons do. ANN consists of groups of interconnected artificial neurons which process the information [7].

### A. *ANN's structure*

The most commonly used structure contains many layers – the first layer is acts as input layer, then one or more play the role of hidden layers, and, finally, there is output layer. Each of them consists of at least one or more neurons. These neurons are connected by connection line, which indicates the flow of information from one node to another and from the input layer to the output via network [8].

### B. *ANN's learning*

ANNs have impressive features in ability to learn by adjusting weighted connections between neurons in network layers. There are different types of learning. The objective of learning process is to find a set of weight matrices which should map any input to a correct output when applied to the network. Below list of the most used learning types [9]:

#### 1) *Supervised learning:*

Desired output for network is also provided with input in this type of learning while training the network. It is possible to calculate an error based on the differences between the target output and actual output of network, which is used to make corrections of network weights.

#### 2) *Unsupervised Learning:*

Only the set of inputs without output is given in case of neural network's learning in this type and its responsibility is to find a pattern with inputs provided.

#### 3) *Reinforcement Learning:*

Reinforcement learning is quite similar to supervised learning, because some feedback is given instead of providing of reward to target output, looking at system performance. The reinforcement learning's main goal is to maximize the reward which system receives during trial-and-error process.

### *C. Backpropagation algorithm*

Backpropagation (BP) [9] stands for "backward propagation of errors". This algorithm is the most common training algorithm of ANNs. The method calculates the gradient of loss function with respect to all the weights in the network. The gradient is fed to the optimization method, which, in turn, uses it to update the weights in attempt to minimize error function.

Desired output for each input value must be known in order to calculate error function gradient in Backpropagation algorithm. It usually considered as learning method with supervising Backpropagation learning algorithm can be split into two phases:

*1) Propagation:*
First of all, training pattern's input's forward propagation through ANN in order to generate the output signal, then backward propagation of output signal through ANN using deltas (difference between targeted and actual output values) of all output and hidden neurons.

*2) Weight update:*
Secondly, after calculating deltas from first phase, multiply its output delta and input activation to get the gradients of weights. Weight gradients' signs indicate where the error increases – this is why the weights should be updated in the opposite direction. Phase 1 and 2 are repeated until network's performance becomes satisfactory and error is minimized.

## IV. SYSTEM DESIGN

ANN will be designed to identify Cyrillic letters written in Braille representation system. Neural network should be able to classify noisy letters as well as letters without noise. Some of number images are collected from the Internet. Some of them are noisy with a type of filter to insure that neural network should be able to identify the true letters and generate an output according to each letter. Network output will be used to identify the corresponding Braille letter [10].

System includes next steps:

- Image acquisition;
- Image processing (filtering and normalization);
- Image segmentation;
- ANN training;
- ANN testing.

Image Acquisition technique plays the role of starting optical Braille character recognition phase. Input files were standardized to JPEG format. JPEG format's usage can free this procedure from using scanners etc. The size of images are 41x60 pixels. The original folder contains 33 images, representing 33 Cyrillic letters (А-Я).

Acquired Braille images are still not very good and need some improvements to be processed to the next stage of optical Braille character recognition that could be achieved using the defined set of image preprocessing techniques, e.g. converting of image to gray scale for easier future processing, because all color components will be compressed into one. Figure 4 shows an example of training images.

Matrix with fixed dots identified through gray level, according to shade ranging from black to white, is passed to matrix with normalized dots which may correspond only to one of possible three values: black, white or paper – during this operation. "Dot" itself will mean "result of optical scanning" in this paper. Noise removal algorithms were applied after converting of images to black and white scale [11]. Figure 5 shows the set of example training images.

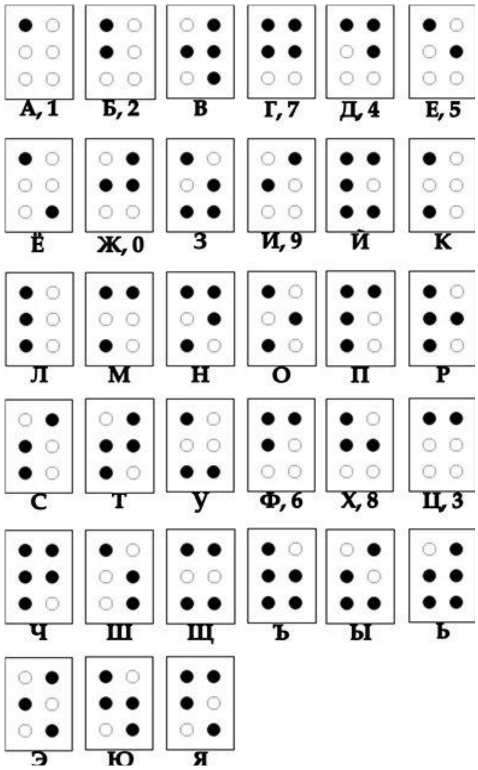


Fig. 5. Set of example training images

In testing process there was one image per each letter to test identification accuracy for neural network, as shown in Figure 6 below.

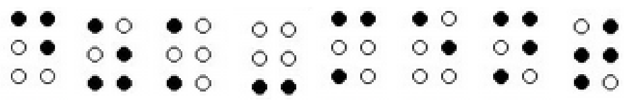

Fig. 6. Examples of testing images

Several parameters were used for artificial neural network training – like learning rate, momentum factor, minimal error, maximal iterations' number, input layer's neurons' number, hidden layers' number and output layer's neurons number, as shown in Figure 7 below [12]. Six neurons were used in the output layer to have the possibility to make binary combination of 6 bits.

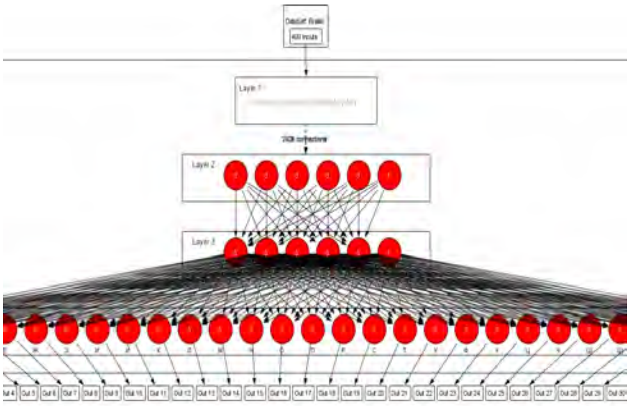

Fig. 7. Used ANN structure topology

## V. RESULTS

Threshold value used to differentiate between the identified and not identified numbers was 90% in result of experiment. Artificial neural network (ANN) system designed uses Backpropagation algorithm at training stage. Accuracies of training and testing were very high. They depend on training algorithms of artificial neural network. The number of images were used in the experiment was 33 images for training and 8 images for testing per test word.

A lot of different parameters were used in the experiment to achieve the goal of the system to identify the number that was written in Braille representation. Table I below shows some parameters that were used in experiment:

TABLE I. TRAINING PARAMETERS

| No. | Parameter | Value |
|---|---|---|
| 1 | Learning Rate | 0,005 |
| 2 | Momentum Factor | 0,2 |
| 3 | Minimum Error | 0,0037 |
| 4 | Number of Iterations | 2713 |
| 5 | Maximum Iterations | 4000 |
| 6 | Number of Hidden layers | 5 |

Changes in any table value listed above would be affect on results of training and testing process, where these values affect training of neural network and time spent on this process and also training and testing accuracy. Figure 8 shows gradient of training which represents performance of neural network.

Identification results using training image set gained 97.1% accuracy which represented average of all letters in training; testing image set has 95% accuracy.

According to system threshold, result obtained from experiment was successful. Tables II, Table III show neural network's training and testing accuracy.

TABLE II. NEURAL NETWORK TRAINING AND TESTING ACCURACY

| Phase | Matching | Percentage |
|---|---|---|
| Training | Accuracy | 97.1% |
| Testing | Accuracy | 95% |

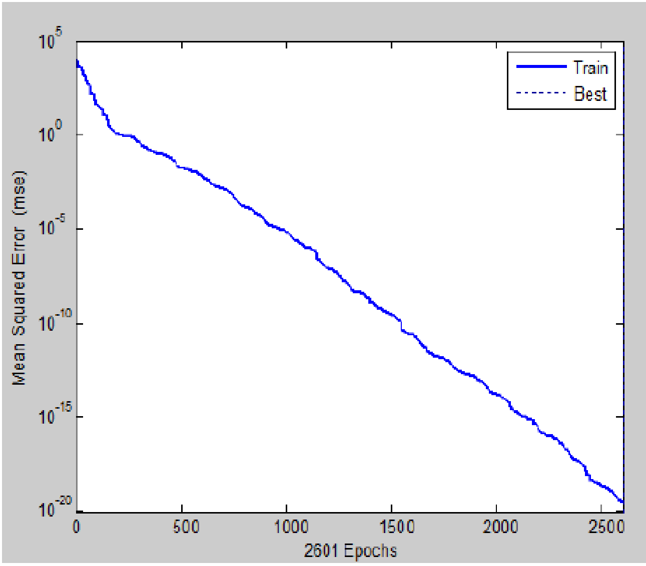


Fig. 8. Neural network performance graph

TABLE III. RESULTS OF BRAILLE RECOGNITION EXPERIMENT

| No. | Input data | Error | Accuracy |
|---|---|---|---|
| 1 | 400 | 0,0057 | 94,75 % |
| 2 | 400 | 0,0043 | 94,67 % |
| 3 | 400 | 0,0034 | 95,34 % |
| 4 | 400 | 0,0039 | 94,77 % |

System's accuracy level was determined during the testing of it on the set of Braille characters by performing the recognition on 10 different images data.

Output window produced by Braille recognizer and error network graph are shown in Figures 4, 5. The user can check the interpretation correctness manually and, therefore, can fix it even without any Braille system knowledge. Depending on scanned image file's quality, optical Braille character recognition using artificial neural networks can reach in mean about 98-100% of automatic correctness [13].

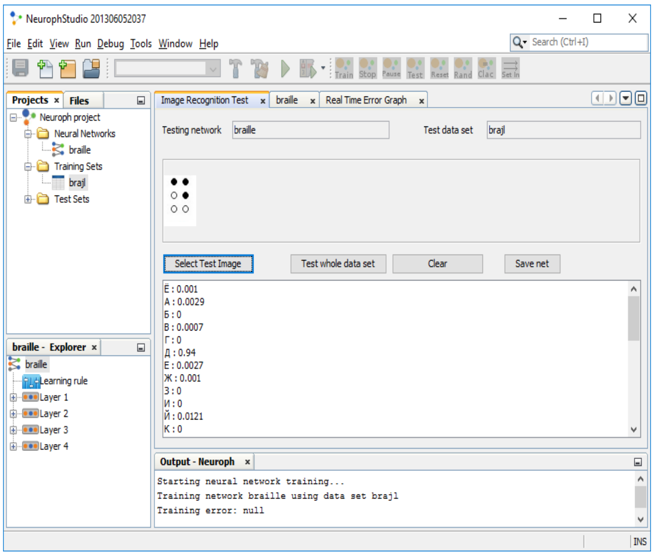


Fig. 9. Recognition step: Neuroph output window

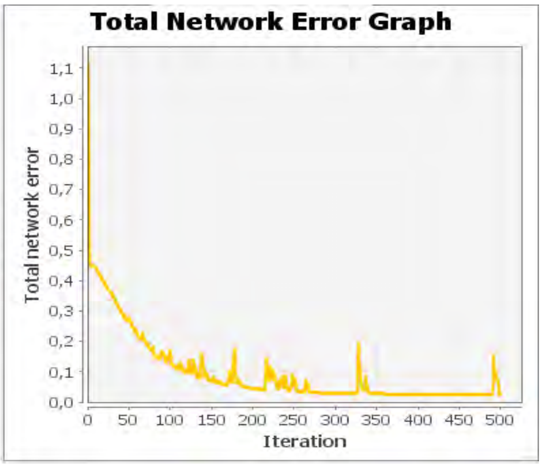


Fig. 10. Error network graph

## VI. Conclusion

Optical Braille character recognition system using artificial neural networks (ANN) method was researched in this paper.

Optical Braille character recognition (OBCR) system is able to build the bridges between blind, visually impaired and sighted people and can convert Braille characters to natural language characters they correspond to. It can help anyone who doesn't know Braille scripting language, but needs to deal with blind people.

System uses multilayer perceptron at its basics, that was implemented using modified Backpropagation algorithm, which allows to reduce the convergence time, and shows very good performance rate.

Designing and implementation of system that identifies letters written in Braille character representation using artificial neural network; practical results has proven success of this system, where many experiments was carried out and result was very high.

According to experiment, result of the identification of characters written in Braille representation using artificial neural network the training accuracy was 95.7% and testing accuracy was 95%.

Based on the experiment, it can be concluded that using of artificial neural network in identification process is successful and very useful because of the easiest way to programming the network architecture and processing time that takes to training and testing with any number of images, it can obtain high identification rate and accuracy.

As a future works it might be to increase training and testing accuracy of ANN up to ~100%.

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