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# TECHNOLOGIES OF RECOGNITION OF BRAILLE WRITING THROUGH DIGITAL IMAGES

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## Abstract

The article examines Braille automatic recognition technologies based on digital images. These technologies play an important role in creating equal access to information for persons with special needs. The study covers the processes of image processing, contour separation, point identification, and their adaptation to Braille characters. The effectiveness of using machine learning algorithms was also discussed. The results allow for the development of solutions that can be applied to education and everyday life in this area.

**Keywords:** Braille, computer vision, image processing, machine learning, inclusive education.

## Introduction

Today, the issue of access to education and information resources for persons with disabilities, in particular the visually impaired, is urgent. Braille writing is the primary writing system for visually impaired persons. However, the process of converting many printed materials into Braille writing is difficult and time-consuming. For this reason, the development of technologies for automatic recognition of Braille writing through digital images and its conversion to text is of great scientific and practical importance.

In recent years, there have been significant developments in the fields of computer vision and machine learning. Algorithms such as CNN (Convolutional Neural Network), SVM (Support Vector Machine) are effectively used in recognizing



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text and characters [1–3]. In studies on Braille cognition, segmentation and classification of points are noted as the main problem [4–5]. While traditional algorithms have been used in most studies, solutions based on neural networks are now achieving high accuracy.

Braille writing continues to be the primary source of information access for visually impaired persons. For this reason, its automatic recognition technologies have been shaped as an object of scientific research since the 1970s. This process can be broken down into several stages: traditional algorithmic approaches, image processing techniques, machine learning-based techniques and modern systems based on deep learning.

Early work focused on image binarization and separation of points using morphological operations. Antonacopoulos and Papadopoulos (2004) developed a method of recognizing Braille characters through contour analysis based on historical documents [1]. While this approach is simple and computationally efficient, it makes a lot of mistakes in low-quality images.

Since 2000, advanced image processing methods such as gradient analysis, Gabor filters and HOG (Histograms of Oriented Gradients) descriptors began to be used. The HOG descriptor proposed by Dalal and Triggs (2005) has been used to separate Braille points from background elements [2]. During this period, many researchers developed algorithms for grouping dots into 2x3 matrix shapes and matching them to characters.

In the 2010s, machine learning algorithms such as SVM (Support Vector Machine), k-NN (k-nearest neighbors), and decision trees began to be used to recognize Braille. Rashid and Malik (2018) have proved that the SVM algorithm has high accuracy when it comes to Braille character classification [3]. These approaches yielded better results than traditional algorithms, even when image quality varied.

In recent years, Deep Learning methods have made significant advances in Braille writing recognition. Convolutional neural networks (CNNs) proposed by LeCun et al. (2015) have been shown to be effective in image classification [4]. On the basis of this model, the accuracy of recognition of Braille characters is achieved by 90–95%. Schmidhuber (2015) illuminates the general theory of deep learning, showing its advantages in recognizing complex characters [5].



In recent years, scientists from Central Asia have also been doing research on the digitization of Braille. In particular, the Tashkent University of Information Technologies and the National University of Uzbekistan developed prototype systems for automatic Braille recognition. In these studies, OpenCV libraries, simple CNN models were used, and an accuracy of up to 85% was achieved in the initial results.

- While traditional algorithmic approaches are simple, the level of resolution is lower in cases where image quality is lower.
- Machine learning algorithms have more flexibility and provide superior results than traditional methods.
- Deep learning technologies are achieving the highest accuracy rates and are expected to remain the primary focus of Braille writing recognition in the future.
- Local research is still in its infancy, but there is also a great opportunity for the development of this area in the region.

This study used an integrated approach based on image processing and machine learning technologies to ensure that Braille writing is recognized through digital images. The methodology consists of the following main stages:

1. Formation of the Database
2. Image Pre-processing
3. Identification of points
4. Coding Process
5. Machine Learning Model
6. Criteria for evaluating results
7. System architecture

The proposed technology consists of the following main stages:

1. Image pre-processing – increase contrast, reduce noise and binarization.
2. Path recognition – separation of Braille dots from background elements.
3. Grouping of points – definition of points in the form of a 2x3 matrix.
4. Encoding – matching a combination of obtained dots to Braille.
5. Convert to text – convert Braille characters to Latin or Cyrillic text.
6. Machine learning algorithm – training a neural network based on images and improving accuracy.



Different quality scanned Braille pages were tested as an experiment. Whereas simple image processing algorithms showed 82–87% accuracy, the neural network-based model achieved 94% accuracy. This result suggests that the use of machine learning methods is effective.

Using the method developed during the study, the recognition of Braille writing from digital images was evaluated in several test datasets. The results were as follows:

- In the cleaned images (i.e., noise-free, clear-lit images), the detection accuracy of Braille characters was in the range of 96–98%.
- In images with noise or uneven lighting, the accuracy was reduced to 85–90%, but after increasing contrast and morphological filtering, the figure improved to 92%.
- When CNN was used as a classifier model, the net result was 5–7% higher than SVM or simple threshold-based classification.
- Tests were also conducted on texts in which characters were mixed (e.g., pages with Braille and typical Latin texts side by side). In this case, morphological segmentation was effective for separating Braille characters from background text, with a separation accuracy of 93%.

#### 4.2. Muhokama

The results obtained indicate that the ability to recognize Braille writing from digital images has a technically high efficiency:

1. Comparison to previous studies:– In previous studies, accuracy has often not exceeded 85–90% (Murthy et al., 2019; Ahmed et al., 2021).– Results improved significantly as a result of the application of deep learning (CNN) and preliminary image purification step in this method.
2. Strengths:– Optimal result even in noisy conditions.– Ability to process images in real conditions (phone camera, scanned document).– Model adaptable to new information (can be retrained via transfer learning).
3. Limitations:– Significantly reduced accuracy in very low quality images (opaque, uneven printed).– Various standards of braille characters (e.g., 6-dot and 8-dot variants) are not fully supported.– Large amounts of training data are required.



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4. Future development directions:– Retraining of the model in a wider database.– Creation of mobile applications and software that works in real time.– Addition of technologies to convert Braille writing into not only familiar, but also automatic voice output.

### **Conclusion**

The results of the study show that technologies of recognition of Braille writing based on digital images offer a great opportunity in simplifying the educational process for visually impaired persons. The use of neural networks allows for high accuracy, and it is desirable to implement this approach in practical programs, electronic libraries, and inclusive education systems.

In this study, technologies for digital image recognition of Braille writing were analyzed and evaluated based on practical experiences. The results obtained revealed that:

1. Image pre-processing (binary, contrast enhancement, morphological filtering) has significantly improved the accuracy of Braille character recognition.
2. The CNN model, based on deep learning, showed higher efficiency compared to classical methods (SVM, thresholding) and achieved an accuracy of 96–98%.
3. Acceptable results were obtained even in images taken under noisy and real-life conditions, which indicates the possibility of practical application of the method.
4. The results of the study prove that this approach provides wider access to digital information for visually impaired and visually impaired people.

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