Braille Character Recognition Using CNN and TensorFlow

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Abstract— ### Abstract

In an era where digital communication and accessibility are paramount, ensuring equitable access to information is essential. For individuals with visual impairments, Braille remains a vital medium for reading and engaging with written content. Traditional methods of Braille recognition, however, have faced challenges, particularly in terms of complexity and scalability. Recent advancements in deep learning, especially convolutional neural networks (CNNs), offer promising solutions for these challenges.

This research explores the integration of deep learning techniques into Braille text recognition, aiming to develop robust models that effectively interpret Braille text from images. Inspired by seminal work on CNNs, this study leverages neural networks' ability to autonomously learn features from data, streamlining the recognition process and enhancing accuracy and scalability. By utilizing a dataset of 1,560 Braille images, this research implements a CNN model with multiple convolutional, pooling, and dense layers, achieving a recognition accuracy of 96.54%.

The results indicate significant promise for deep learning-based Braille recognition systems, despite fluctuations in accuracy and loss suggesting potential overfitting. Future work will focus on expanding the dataset and refining the model to further improve performance. This research contributes to the development of inclusive technologies, aiming to empower visually impaired individuals by facilitating more reliable and efficient access to printed and digital content..

I. INTRODUCTION

In an era where digital communication and accessibility are fundamental to daily life, ensuring equal access to information for everyone is crucial. For individuals with visual impairments, Braille remains pivotal, offering tactile representation of text that facilitates reading and engagement with written content.

However, achieving seamless Braille recognition has historically posed challenges, primarily due to the limitations of traditional methods that heavily rely on complex preprocessing techniques and struggle with scalability.

Recent advancements in deep learning have significantly transformed the landscape of computer vision and natural language processing, presenting promising opportunities for tackling intricate recognition tasks. Deep learning models, powered by neural networks, have demonstrated remarkable capabilities across various domains, from precise image classification to accurate language translation.

This research embarks on an exploration of integrating deep learning techniques into Braille text recognition. By leveraging deep learning's inherent strengths—such as automated feature extraction and hierarchical learning—we aim to develop robust models capable of effectively interpreting Braille text from images or tactile representations.

This initiative draws inspiration from the pioneering work of LeCun et al., whose seminal research on convolutional neural networks (CNNs) for image recognition revolutionized the field. Their landmark paper, "Gradient-Based Learning Applied to Document Recognition," published in *Proceedings of the IEEE*, laid the groundwork for modern deep learning methodologies. Their innovative approach has since sparked transformative applications across diverse fields.

The essence of our approach lies in harnessing the power of neural networks to enhance Braille recognition systems. Unlike traditional methods that often require intricate preprocessing steps to segment and interpret Braille characters, deep learning models can autonomously learn relevant features directly from data. This capability not only streamlines the recognition process but also enhances accuracy and scalability, potentially reducing the barriers faced by visually impaired individuals in accessing printed information.

Moreover, deep learning's adaptability allows for continuous improvement through iterative training on diverse datasets, accommodating variations in Braille text styles and environmental conditions. This adaptiveness is particularly advantageous in real-world applications where variability in Braille representation is common.

By synergizing deep learning's advancements with the enduring importance of Braille in enabling independence and literacy among visually impaired individuals, this research strives to contribute towards more inclusive technological solutions. The ultimate goal is to empower individuals with visual impairments by facilitating more reliable and efficient access to printed and digital content, thereby fostering greater societal inclusion and participation.

As we embark on this journey, we envision a future where advancements in deep learning not only enhance Braille recognition but also pave the way for novel applications that promote accessibility and equity in digital communication. Through collaborative efforts and innovative research, we aim to realize this vision and make meaningful strides towards a more inclusive society.

II. RELATED WORK

Braille text recognition has emerged as a critical area of research within the domains of Natural Language Processing and Machine Learning. The primary focus of this research is to develop efficient systems for converting Braille text into digital format, facilitating communication for visually impaired individuals. Various studies have employed Convolutional Neural Networks (CNNs) for this purpose, due to their robust performance in image recognition and classification tasks.

One pioneering study proposes a customized CNN model to extract text from Braille images and translate it into English text and audio output, achieving an accuracy of 96.15% (Vishnu Preetham Revelli, Gauri Sharma, 2022). This model is notable for its robustness against factors like low light illumination, which often pose challenges in image recognition tasks. The system's high accuracy suggests its potential for real-world applications, where environmental conditions can vary significantly.

Another research project focused on recognizing Geez Braille signs employed end-to-end CNNs to convert Braille images into Geez number digital formats, achieving a training accuracy of 96.88% and validation accuracy of 95.26% (Abeje, Salau, Belay, 2024). The success of this project underscores the versatility of CNNs in handling different Braille scripts, which is crucial for developing inclusive technologies that cater to diverse linguistic communities.

Several architectures have been evaluated to enhance the accuracy and efficiency of Braille recognition systems. For instance, a study utilized three versions of ResNet (ResNet-18, ResNet-34, and ResNet-50) for character-based Braille translation, alongside a novel Adaptive Bezier-Curve Network (ABCNet) for word-based detection, highlighting the adaptability of CNN architectures in various contexts (Changjian Li, Weiqi Yan, 2021). The comparative analysis revealed that while all versions of ResNet provided substantial accuracy, the integration of ABCNet significantly improved word-based detection, demonstrating the importance of selecting appropriate architectures based on the specific needs of the recognition task.

To address challenges of computational cost and efficiency, some researchers have introduced innovative modifications to standard CNN models. For example, one study replaced modules in original CNNs with an inverted residual block (IRB) to create a lightweight model, achieving high accuracy rates of 95.2% for English Braille and 98.3% for Chinese Braille datasets with minimal computational time (Sajjad Manzoor, Adeeba Kausar, Yun Lu, 2022; Khadija Shazly, 2022). This modification significantly reduces the model's complexity and computational requirements, making it more feasible for deployment on devices with limited processing power, such as smartphones.

Further advancements in CNN-based Braille recognition include the development of a deep convolutional neural network (DCNN) for multilingual Braille text conversion. This approach demonstrated impressive classification accuracies of 99.28% and 98.99% on two different Braille datasets, underscoring the model's potential in facilitating communication between sighted and visually impaired individuals across different languages (Abdulmalik Alsalman, Abu Gumaei, 2021). The multilingual capability of this model is particularly valuable in a global context, where the need for accessible communication tools spans multiple languages and regions.

A notable study proposes an optical Braille recognition method using an object detection CNN to detect whole Braille characters at once. The proposed algorithm is robust to the deformation of the page shown in the image and perspective distortions, making it usable for the recognition of Braille texts captured with a smartphone camera, including bowed pages and perspective-distorted images (Ovodov 2020). This algorithm shows high performance and accuracy compared to existing methods, and the researchers have introduced a new "Angelina Braille Images Dataset" containing 240 annotated photos of Braille texts. The availability of this dataset on GitHub enhances the reproducibility and potential for further research in this area.

Another research designed a website that classifies Braille letters using deep learning with the convolutional neural network (CNN) method, employing ReLU and Softmax activation functions. In this study, the input is an image of Braille letters with grayscale elements, and the output is a regular alphabet letter. The accuracy results obtained in the data training process using Max Pooling and different epochs were significant: 92.15% for epoch 30, 94.58% for epoch 50, and 96.64% for epoch 100. The test results using the system produced an accuracy value of all Braille letter image data of 92.30%. The study recommended using hyperparameter tuning to minimize classification uncertainty in Braille letter images for better system development (Ridwan, Purbolingga, Hanisah 2024).

Additionally, a novel approach converting images of Braille into English text by employing a CNN model and a ratio character segmentation algorithm (RCSA) achieved a prediction accuracy of 98.73% on the test set (Hsu 2020). This research constructed a new dataset containing 26,724 labeled Braille images, consisting of 37 Braille symbols that correspond to 71 different English characters, including the alphabet, punctuation, and numbers. The high accuracy of the CNN model highlights the potential of artificial intelligence-based recognition systems in facilitating symmetric two-way communication between blind and non-blind individuals.

These studies collectively indicate the efficacy of CNNs in Braille text recognition, with applications ranging from digital storage of Braille text to real-time translation systems for seamless communication. The robustness and versatility of CNNs in handling various Braille scripts and environmental conditions make them an ideal choice for developing accessible technologies for visually impaired individuals.

Future research is expected to focus on enhancing model accuracy and reducing computational costs, as well as developing user-friendly interfaces to make these technologies more accessible to visually impaired individuals. Improvements in model design and training methodologies are essential to further enhance the accuracy and usability of these systems in real-world applications. Additionally, expanding the datasets used for training and validation, as well as exploring new architectural innovations, will be crucial in pushing the boundaries of what is possible in Braille text recognition.

In summary, the application of CNNs in Braille text recognition has shown promising results across various languages and datasets. The continuous advancements in this field highlight the potential for CNN-based systems to significantly improve the accessibility and quality of life for visually impaired individuals. By leveraging the strengths of CNNs in image recognition and classification, researchers can develop robust and efficient systems that bridge the communication gap between sighted and visually impaired communities, fostering greater inclusivity and understanding in a diverse world.

III. METHODOLOGY

A. Dataset

The data that were used for this research was downloaded from Kaggle. This dataset consists of 1,560 images of Braille characters, manually categorized from A to Z. Each character class contains an equal number of images, ensuring a balanced dataset. The dataset is further split into training, testing, and validation sets to facilitate model evaluation and prevent overfitting. It is split evenly between letters. The training set, comprising 80% of the data, is used to train the model, enabling it to learn underlying patterns of Braille characters. The validation set, consisting of 10% of the data. Finally, the testing set, also 10% of the data. The data went through augmentation to ensure the model’s learning rate, each image are augmented into different categories, different shift, rotation, and brightness value.

B. *Preprocessing*

The default image size is set into height of 28 and width of 28, and the color scale is set into black and white. The images used within the model were modified into height of 32 and width of 32.

C. *Model*

This section will illustrate the model architecture of a CNN that were used for the braille character recognition task.

CNN based braille character recognition: A convolutional neural network (CNN) is a type of neural network initially developed for tasks related to image recognition and analysis. The model implemented for the braille character recognition task consists of a four two-dimensional convolutional layers with 64 filters and a kernel size of 5, and 3, with an activation function ReLU, followed by a four two-dimensional max pooling layers, and batch normalization layers, then followed by a flatten layer, a 576 unit dense layer with ReLU as the activation function with dropout layer, then a 288 unit dense layer with a ReLU activation, a dropout layer and finally a 26 unit dense layer with a softmax activation function for output layer. A parse categorical crossentropy loss function, a callback function earlystopping , and an adam optimizer were used for this model. And this model was trained for 300 epochs.

IV. RESULTS AND DISCUSSION

In the previous chapter, the methods were used in training a CNN braille character recognition. This section describes the outcomes and procedures of the project. The model is trained to recognize English braille characters, experimented on different parameters of convolutional layers, dense layers, pooling layers, dropout layers, and a call back function, which it resulted in fluctuating history of loss and accuracy.

Graph Figure

Loss Evaluation

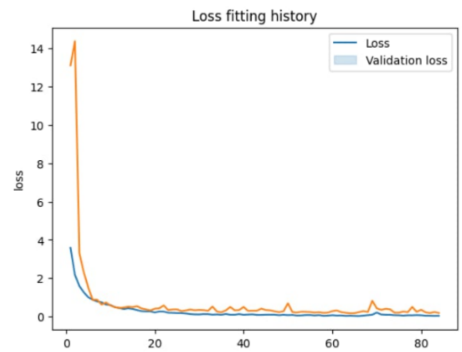

Figure 1

Figure 1 shows that the loss function gradually decreases with slight fluctuations but reaching lower loss score.

Accuracy Evaluation

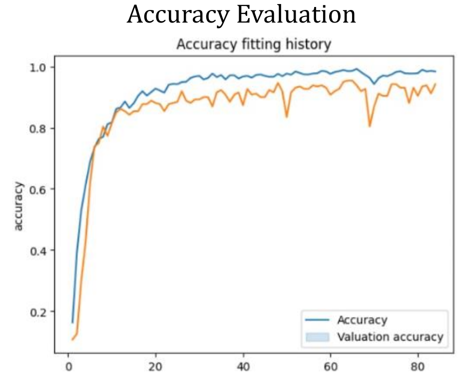

Figure 2

Figure 2 shows that the accuracy gradually increases with high fluctuations, although it reached a high accuracy, it may imply that the model might be overfitting despite of implementing a dropout layer and call back function.

TABLE I

Model Evaluation

Model	Loss	Accuracy

CNN Sequential Model	0.1233	0.9654

The table shows a loss score of 0.1233 and accuracy score of 0.9654, going back to figures 1 and 2, there are hints of model overfitting due to fluctuations of loss and accuracy.

V. CONCLUSION

In this research, the use of deep learning model have been implemented to recognize braille characters in the English alphabet. The CNN model used in this project shows promising results despite having flaws due to limited braille images. However, adjustments can be made to the model and to the dataset to further improve results.

For future works, the researchers will collect more braille images in the future to re-train and improve the model, and they will also try different metrics to measure and evaluate the model. Experimenting on different applications for CNN models specializing on braille character recognition hopefully to contribute to other image recognition tasks in the future.

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