Handwritten Arithmetic Equation solver

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Abstract

The Handwritten Equation Solver is a project aimed at accurately recognizing and evaluating handwritten mathematical expressions. This task is essential across various fields, including education, document processing, and handwriting recognition. Handwritten equations present challenges due to their mix of digits, operators, and parentheses. To address this, the project proposes a multi-step approach involving dataset curation, image segmentation, preprocessing, CNN-based character classification, and algorithmic reconstruction of equations. Through techniques such as augmentation, thresholding, and contour extraction, the system achieves robustness and accuracy in deciphering handwritten equations. Simulation results demonstrate high performance, making the Handwritten Equation Solver a promising tool for practical applications requiring precise mathematical expression recognition from handwritten inputs.

Keywords
Handwritten Equations, Deep Learning, CNN, Automation, Image Processing

1) Introduction

Almost every branch of science, including physics, engineering, medicine, economics, and others, heavily relies on mathematics. In the field of computer vision, handwritten mathematical expression recognition remains one of the most difficult tasks[1].

Convolutional neural networks (CNN) are used in a handwritten equation solver, which is an artificial intelligence application for picture recognition and mathematical problem solving. CNNs are perfect for jobs like solving equations because of the astonishing accuracy with which they can recognize and understand handwritten characters and symbols thanks to developments in deep learning techniques, especially in computer vision. A key component of deep learning methods in image processing is the Convolution Neural Network (CNN). CNN can now perform complex visual tasks thanks to advancements in processing power and deep learning techniques, however it still requires a large amount of training data.[2].

Deep Convolutional Neural Network (CNN) learning has demonstrated exceptional performance in the areas of pattern recognition, machine learning, and image classification during the past several years. CNN is the most widely used model now in use. It offers the highest recognition accuracy possible for object identification, segmentation, human activity analysis, super resolution images, object detection, scene understanding, tracking, and image captioning [5].

Determine the answer to the handwritten equation for each correctly identified handwritten equation by identifying it in the image. Because each handwritten character has a unique shape and structure, the most challenging aspect of every handwriting is extracting its features. Convolutional neural networks, which don't require any preexisting features for the categorization of particular characters, are used to handle this challenge [4].

2) Literature Review

One of the first efforts on handwritten equation solving with CNNs was given by Patil et al. (1999). Their work established the viability of using deep learning methods to this problem, which paved the way for further investigation. However, their model's performance might not meet modern standards because of the constraints of processing power and data available at the time.
In order to improve handwritten equation recognition, Hossain et al. (2018) proposed an approach that combines CNNs with additional techniques including picture preparation and post-processing algorithms.

A CNN-based handwritten equation solver was introduced by Kawade and Dhanokar in 2021. Their study probably incorporated improvements in deep learning architectures and training procedures, building upon earlier research. Through the use of CNNs, they were able to solve handwritten equations with remarkable accuracy.

Priyadharsini et al.'s (2022) main goal was to employ CNNs to examine how well a handwritten equation solver performed. In order to maximize the model's accuracy and effectiveness, their research may have looked at different CNN architectures, hyperparameters, and training techniques. They were able to give important insights into the advantages and disadvantages of CNN-based methods for this task by analyzing the system's performance.

By offering a thorough investigation on handwritten equation solving using CNNs in the context of intelligent systems and computer vision, Arya et al. (2023) made a significant contribution to the area. They most likely used advanced methods like data augmentation and transfer learning in their work to improve the model's capacity for generalization and resilience to handwriting style differences.

Early research on the recognition of handwritten mathematical expressions was given by Matsakis (1999), who concentrated on the creation of algorithms for structural analysis and symbol identification. By defining key ideas and procedures, this foundational study set the stage for further investigations.

A convolutional neural network (CNN)-based method for identifying handwritten digits in arithmetic operations was presented by Wang et al. in 2020. Although they mostly concentrated on digit identification, their research showed how well CNNs handled handwritten characters, which offered important insights for more intricate mathematical expression recognition systems.

A handwritten mathematical problem solver using machine learning approaches was presented by Shinde et al. (2022). They most likely used preprocessing techniques to identify characteristics in handwritten symbols, then a regression or classification model to decipher the mathematical statement. The intricacies of their technique and performance indicators would offer significant perspectives on the practicability and efficacy of their strategy.

Priyadharsini and colleagues (2022) conducted a study to examine the efficacy of a CNN-based handwritten equation solver, with the objective of improving the recognition system's precision and resilience. To outperform earlier methods, their efforts probably concentrated on CNN architecture and training technique optimization. Their investigation provided insights that might influence comparable systems' design decisions and parameter adjustment techniques.

An technique based on deep learning and designed especially for handwritten arithmetic problem solving was presented by Karegowda et al. in 2022. They most likely used a combination of training methods and neural network designs designed to handle arithmetic symbols and operations. They might evaluate the state-of-the-art performance in handwritten equation solving problems by contrasting their results with those of other methods, which would give useful benchmarks.

3) Methodology:

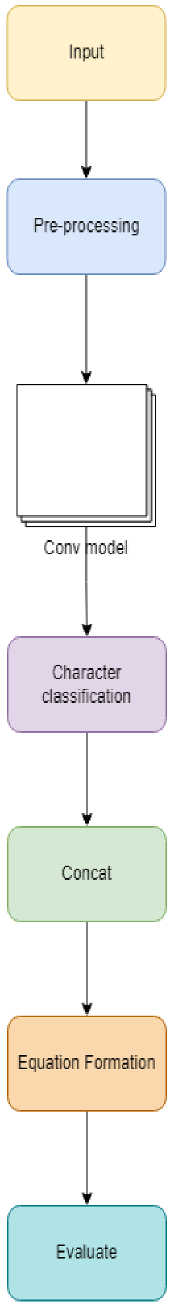
In the domain of Handwritten Equation Solver, accurately recognizing and evaluating handwritten mathematical expressions is crucial for various applications, including educational tools, document processing system, and handwriting recognition software. Handwritten mathematical expressions often contain a combination of digits, mathematical operators, and parentheses, making their recognition challenging. For instance, deciphering complex equations or mathematical expressions written by hand can be arduous for both humans and machines. Thus, the goal of our project is to develop a robust handwritten equation solver capable of accurately recognizing and evaluating mathematical expressions from handwritten inputs.

To achieve this goal, we propose a multi-step approach. Initially we gather a diverse dataset of handwritten mathematical equations, comprising digits(0-9) mathematical operators(/,*,+,-), and parentheses. This dataset is augmented using techniques such as rotation, scaling and translation to increase variability and improve model robustness. Subsequently, we employ image segmentation techniques to extract individual characters from the handwritten equations. Preprocessing steps, including grayscale conversion, thresholding, and noise reduction, are applied to enhance image clarity and remove irrelevant details.

For character classification, we train a convolution neural network (CNN) using deep learning architectures. The CNN model is designed to take character images as input and output predicted class labels, optimizing for accuracy and generalization through experimentation with various hyperparameters and network architectures. Evaluation on a validation set guides the fine-tuning and refinement of the model.

Once character classification is achieved, we develop algorithm to parse the sequence of classified characters and reconstruct the original mathematical equation. This involves handling operator precedence and parentheses grouping to ensure accurate equation formation. Additionally, verification logic is implemented to validate the equation for correctness and mathematical consistency, detecting syntax errors and division by zero. Error detection and correction mechanism may be incorporated to address inaccuracies in character classification or segmentation.

3.1 Architecture



3.2 Preprocessing

The preprocessing begins by converting images to grayscale for simplicity. Inverting grayscale colors enhances foreground visibility. Thresholding creates binary images, distinguishing foreground objects like characters. Contours extraction identifies character regions. The largest contour defines bounding boxes, used to crop and resize characters to a standard size. Finally, these preprocessed character images are reshaped into vectors for machine learning analysis. This systematic approach ensures effective segmentation and transformation of handwritten equation images, laying a solid foundation for accurate character recognition and classification within the dataset.

3.3 Dataset

The dataset utilized in this research comprises images created using the Microsoft Paint application. Microsoft Paint is a widely accessible graphics editor that allows users to create and modify images using basic drawing tools such as pencil, brush, shapes, and color palette.

Dataset Link : [Dataset]

3.4 Simulation Result

Handwritten equation solver has been done using CNN on GPU of Google Colab.

$$Precision = TP/(TP + FP)$$

$$Recall = TP(TP+FN)$$

$$F1\text{-}Score\ = 2 * precision * Recall / (Precision / Recall)$$

Results:

Table 3.4.1

Training Accuracy	Testing Accuracy
0.9570	0.87

Table 3.4.2

Precision	Recall	F1-score	Accuracy
1.00	1.00	1.00	1.00

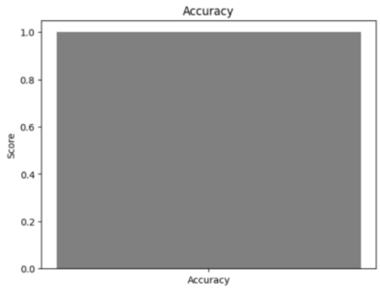


Fig 3.4.1 Accuracy

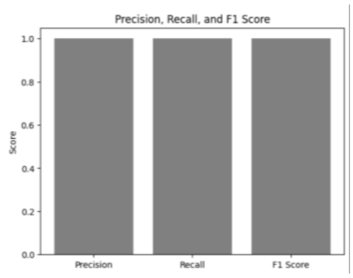
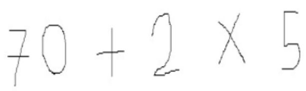


Fig 3.4.2 Precision, Recall, F1-Score

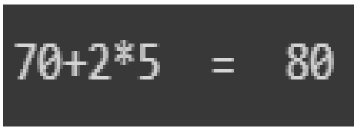
Results:



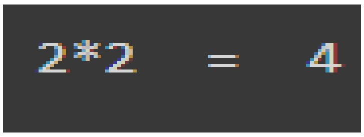
Input Fig. 3.4.3

Input Fig. 3.4.4

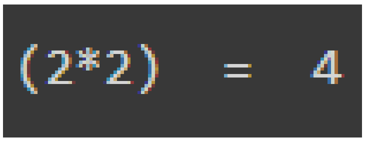
Input Fig. 3.4.5



Output Fig. 3.4.6



Output Fig.3.4.7



Output Fig.3.4.8

Conclusion :

In this study, we proposed a robust methodology for developing a Handwritten Equation Solver capable of accurately recognizing and evaluating mathematical expressions from handwritten inputs. Leveraging deep learning techniques, particularly Convolutional Neural Networks (CNNs), we addressed the challenges associated with handwritten equation recognition and solved equations with high accuracy.

Through the curation of a diverse dataset of handwritten mathematical equations and augmentation techniques like rotation, scaling, and translation, we enriched the variability and robustness of our model. Image segmentation techniques facilitated character extraction, while preprocessing steps such as grayscale conversion, thresholding, and noise reduction enhanced image clarity, laying the groundwork for effective character recognition.

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