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DOODLECALC: A REAL-TIME HANDWRITTEN LINEAR ALGEBRA SOLVER USING DEEP LEARNING

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Abstract
In educational technology, innovative tools that enhance student engagement and learning efficiency are crucial. This innovative project proposes the development of a Doodle-Based Handwritten Linear Algebraic Math Recognizer and Solver, an approach to solving linear algebraic problems through interactive doodling. Utilizing advanced image processing and deep learning techniques to achieve accurate recognition and solving capabilities, the core objective is to create a system that allows users to draw linear algebraic expressions and equations directly, which are then recognized, parsed, and solved in real-time. Key components of the project include real-time feedback mechanisms to assist users as they draw, and a robust parsing engine that translates doodle sequences into structured algebraic formulas. By integrating educational technology with interactive doodling, this project seeks to offer innovative strategies that supports and enhance the learning experience in linear algebra and broaden the accessibility of mathematical computations. DoodleCalc is designed to revolutionize mathematical problem-solving by offering an intuitive and interactive platform accessible to users of all levels with its user-friendly interface and real-time feedback.

INTRODUCTION

Traditional methods for solving linear algebraic equations may not support interactive learning and often prove in-efficient and error prone while solving equations. This limitation hinders efficient problem-solving especially in education and professional domain. While existing image-based equation solvers have made progress, they often lack real-time capabilities, face challenge in recognizing complex expressions and user-friendliness. This project aims to describe the development and implementation of a real-time handwritten linear algebraic expression solver called Doodle Calc.

The background of this system involves prevail over several challenges: capturing real-time stroke data from user-drawn doodles [1], accurately recognizing and parsing algebraic symbols, and providing immediate feedback to users as shown in Fig. 1. DoodleCalc is intended to overcome these limitations as well as the limitations of traditional linear algebraic problem-solving methods, which often fail to engage students fully and can be time-consuming. The technology interprets and translates handwritten doodling into precise algebraic formulae by utilizing cutting-edge image processing and deep learning algorithms [5]. By doing so, DoodleCalc improves the interactivity and accessibility of mathematical problem-solving providing a user-friendly platform where linear algebraic expressions can be drawn directly by users.

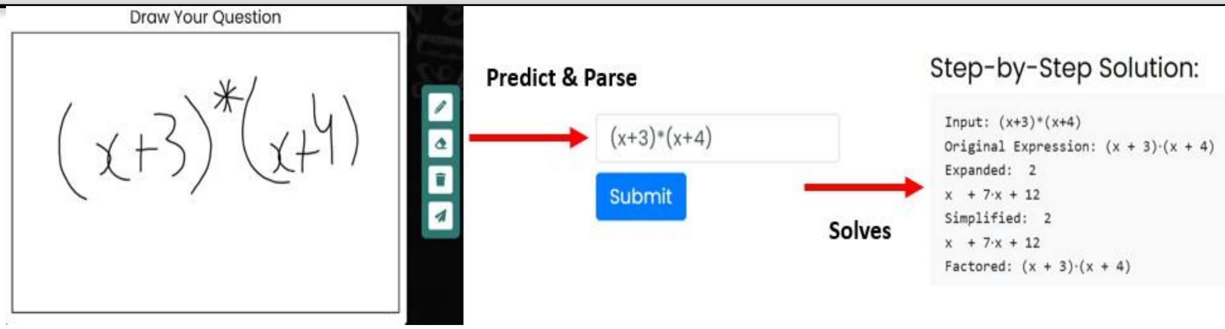

Fig. 1: A brief illustration of proposed method

The system also incorporates real-time feedback mechanisms to guide users and enhance their problem- solving experience. The project builds upon existing research in handwriting recognition [8], pattern recognition [4], and symbolic computation to create a robust and user-centric solution. This proposal details the development process for DoodleCalc, including its innovative approach to making mathematical computations more accessible and engaging. By addressing the need for interactive educational tools, DoodleCalc aims to revolutionize linear algebraic problem-solving and contribute significantly to educational technology [3]. DoodleCalc offers a more natural alternative, allowing users to draw expressions as they would on paper, with the system interpreting and solving them using state-of- the-art deep learning models.

II-LITERATURE REVIEW

As per literature review, there exist systems related to handwritten mathematical expression recognizer, which parse the user entered math symbols using various techniques like AI models or other related techniques in order to build the system which parse the user input correctly, keeping in view the previous systems some of them are discussed here:

ICAL: Implicit Character-Aided Learning for Enhanced Handwritten Mathematical Expression Recognition (2024): It focuses on improving the handwritten mathematical expressions using implicit character-level information to enhance overall accuracy and efficiency of system by implementing machine learning techniques for better understanding. It proposes the ICCM to predict implicit character sequences and use a Fusion Module to merge the outputs of the ICC and the decoder, thereby producing corrected predictions. The model focusses only on character level recognition and might not be suited for variable character of Doodle based input, where symbols can highly irregular [5].

SAM: Semantic Graph Representation Learning for Handwritten Mathematical Expression Recognition (2023): It improves the recognition of complex mathematical 2 structures by representing expressions as semantic graphs, enhancing the model's ability to understand spatial relationships between symbols. It proposes a method where mathematical symbols and their relationships are modeled as nodes and edges in a graph. It aims to improve accuracy using GNNs. It designs a semantic aware module (SAM), which projects the visual and classification feature into semantic space. The cosine distance between different projected vectors indicates the correlation between symbols. And jointly optimizing HMER and SIL can explicitly enhances the model's understanding of symbol relationships. SAM can be easily plugged into existing attention-based models for HMER and consistently bring improvement. GNNs (Graph Neural Networks) may not be as adaptable to different types of handwriting styles. The need for advanced graph- based methods might require significant computational resources, making it less efficient for real-time applications [8].

NAMER: Non-Autoregressive Modeling for Handwritten Mathematical Expression Recognition (2023): NAMER comprises a Visual Aware Tokenizer (VAT) and a Parallel Graph Decoder (PGD) to improve the efficiency of recognizing handwritten mathematical expressions and dealing with complicated expressions. To improve identification accuracy and speed, the research investigates how these models might be combined with graph-based representations to efficiently capture

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the connections between symbols. The paper demonstrate how non-autoregressive modeling can enhance the efficiency and effectiveness of recognizing complex handwritten mathematical expressions. Initially, the VAT tokenizes visible symbols and local relations at a coarse level. Subsequently, the PGD refines all tokens and establishes connectivity's in parallel, leveraging comprehensive visual and linguistic contexts. Faces challenges in achieving real-time processing speed. It may also struggle with highly complex expressions. [7].

III- PROPOSED FRAMEWORK

The proposed framework of **DoodleCalc** is a modular pipeline designed to convert handwritten linear algebra input into accurate, real-time computational solutions. It involves several interconnected stages that perform input acquisition, preprocessing, character recognition, equation parsing, and symbolic solving. The framework is designed for low-latency performance, scalability, and high accuracy. This approach works by providing user interface to draw linear algebraic equations and using advanced image processing and deep learning technique to interpret and solve the user entered expressions effectively. The key ability of DoodleCalc is to provide immediate feedback which is shown in fig. 2. Re implementing the system with focus on various aspects that previous systems lack. It will also provide improved user interaction and learning experiences in mathematics. It's not just a way to enhance linear algebraic problem-solving but to transform the way mathematical education is delivered by addressing the current gaps in existing systems. DoodleCalc can significantly enhance mathematical problem-solving experiences. It emphasizes the modern learning system and its impacts in future.

Fig.2: Framework of proposed Method

IV-DATASET

The dataset has been collected from Kaggle, that contain photos of mathematical symbols with 69 classes and the total dataset contains 34,500 images. Different classes are shown in Table I which demonstrates the dataset.

Table I: Dataset Description

Sr. No.	Classes	Sr. No.	Classes
1	+	8	X
2	-	9	Y
3	/	10	Z
4	*	11	(
5	1	12	)
6	2	13	=
7	3	14	geq

V- ALGORITHM WORKING

After studying various publications and papers on Handwritten Mathematical Expression Recognition in general, we discovered that various techniques are utilized for it. In computer science, there are various techniques such as Machine Learning, Deep Learning, Supervised Machine Learning, Neural Networks, Regression.

This research uses CNN (Convolutional Neural Network) to predict the user entered doodles and parse them correctly. Results show that the model achieves the best accuracy shown in Table II, along with the graph in Fig. 3 that also shows the training and accuracy less error rate. When we run the model, The prediction module works in such way that it classifies the dataset labels as shown in Fig. 4.

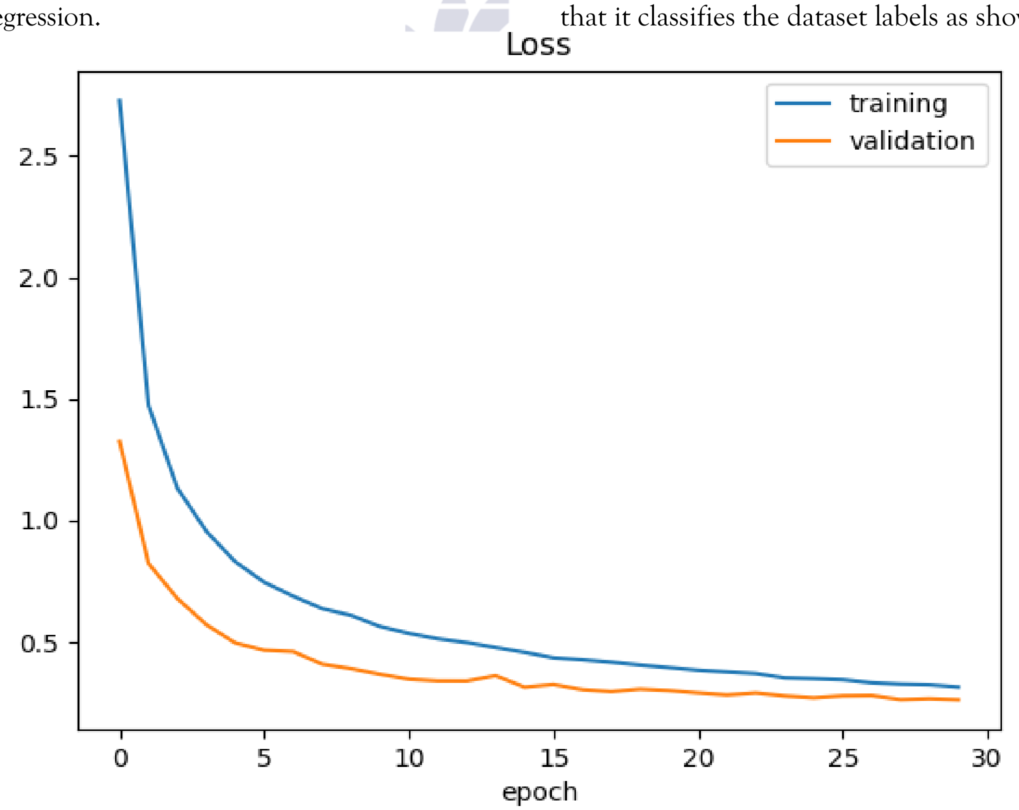

Fig. 3: Graphs demonstrate training and validation accuracy.

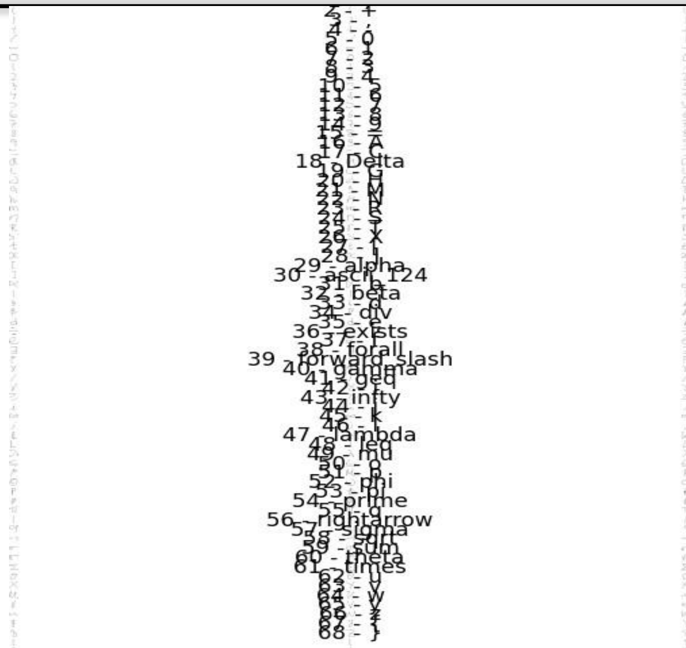

Fig. 4: Illustrates the dataset Labelling.

It also preprocesses the captured image then identify user entered strokes in image and predict them based on labels classified. It also uses SumPy to provide solution of parsed equation, which leads to solve user entered equations in real time after predicting them it provides detailed step by step solution.

Table II: shows the performance accuracy of our model.

Training Accuracy	0.9020 (90.20%)
Validation Accuracy	0.9205 (92.05%)
Test Accuracy	0.9164 (91.64%)

VI- RESULTS & DISCUSSIONS

Existing image-based equation solvers have made progress, they often lack real-time capabilities, face challenge in recognizing complex expressions and user friendliness. DoodleCalc enhance learning and providing user-friendly approach to solve complex expressions through deep learning techniques as shown in Fig. 5. It recognizes input accurately to process and solve expressions to provide user real-time feedback providing intuitive and easily accessible interface to users to input expressions by doodling and enhance the mathematical learning and problem-solving skills for students by providing them an interactive tool. Re-implementing the system with focus on various aspects that previous systems lack. It serves as an innovative educational tool that helps learning algebra. Apart from traditional methods of learning students will seek new way to improve their learning. It also promotes accessibility to mathematical empowering by creative thinking allowing users to express ideas visually. Not only for students it will help teachers in educational institutes providing new way to enhance and interactive classroom environment.

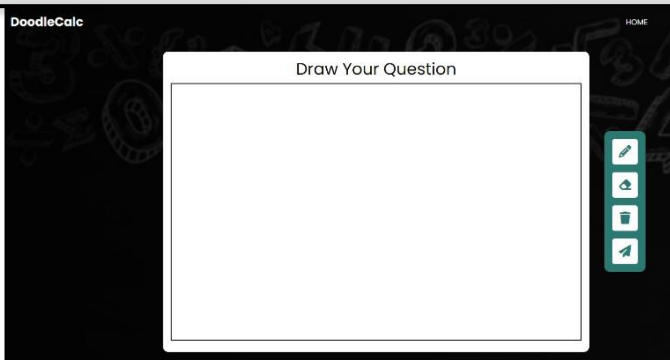

Fig. 5: Showing interactive user interface

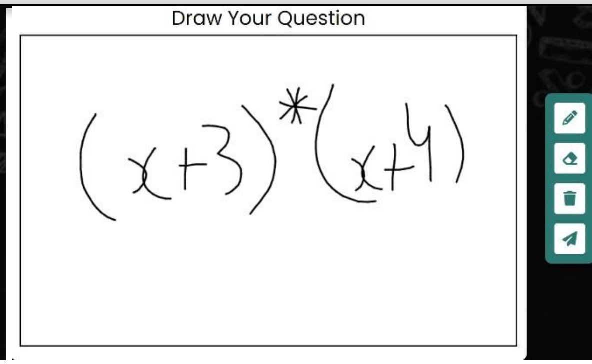

Fig. 6: User drawn Doodle

The use of deep learning ensures accurate recognition of a wide range of handwriting styles minimizing the errors in equation input. This interactive approach saves user time applying traditional methods to solve the expressions through efficient input and calculations. By providing users to visually create and solve linear algebraic expressions provide unique, engaging and appeals to students, making learning algebra more accessible and fun. Challenges include dependency on hardware compatibility, limited user awareness and potential accuracy to identify similar symbols. Devices with connected internet connection are more likely to have fast real-time feedback.

VII- CONCLUSION

This project aims to present an advanced human-computer interaction for mathematical problem-solving. It uses deep learning to revolutionize the way linear algebraic expressions are solved using doodle-based input to improve the accuracy and efficiency. Moreover, it provides the immediate solution of recognized expression in real-time creating a user-friendly environment. The successful implementation of this project may have a big influence on educational technology and provide an effective tool for interactive learning by empowering users to interact with mathematics in a more natural and interactive way.

VIII- FUTURE WORK

The Functionality of this can be increases based on that different methods other than algebra can be added like quadratic algebraic expressions, statistics, trigonometry, calculus, etc. and its accuracy can be increased in future using various modified techniques.

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