iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** V **Month of publication:** May 2021

DOI: https://doi.org/10.22214/ijraset.2021.34233

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue V May 2021- Available at www.ijraset.com

Handwritten Equations Solver using CNN

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Abstract: ***Robust handwritten character recognition is a tricky job in the area of image processing. Among all the problems handwritten mathematical expression recognition is one of the complicated issues in the area of computer vision research. Segmentation and classification of specific characters makes the task more difficult. In our project, handwritten numbers and symbols are read and further addition, subtraction and multiplication operations are carried out. This project involves the study of Convolutional Neural Networks and deployment of the model using Flask. Various libraries such as opencv, keras etc. Were used for this project. For classification of specific characters we apply Convolutional Neural Network. Each of the correct detection, character string operations is used for the solution of the equation. Finally the experimental results show the great effectiveness of our proposed system. This system is helpful for students who want to get the answers to the handwritten equation. This can be further expanded to more complex equations and can be trained on more user data to further improve accuracy.***

Keywords: Convolutional Neural Networks, opencv, find Contours, pooling, ReLU.

I. INTRODUCTION

The mathematical problems that we can solve today, with the help of various applications is a boon. Various applications give the solution for most of the complex problems. So, with respect to the mathematical expressions one of the major aspect is recognising the digits and the mathematical symbols online. It is easy for us to recognize but this lies as a difficulty is the computer's path as the strokes and curves that we use when writing are different from the digital text.

Further after recognizing the digits and symbols, we move onto solving the expression. These handwritten equations are solved by training the model using Convolutional Neural networks and adding layers and activation functions to the layers of our Neural Network. The dataset for the project consists of all the handwritten numbers from 0-9 and also includes the signs such as +,-,*,/ and other mathematical operations. The model uniquely identifies each symbol and trains the model based on the input from each of these inputs.

II. DATASET

Dataset for Handwritten digits and symbols recognition is taken from these datasets that contain handwritten digits from 0 to 9 and other handwritten symbols such as '+', '-', 'x', etc. The dataset contains about 15,000 images of each category.

III. METHODOLOGY

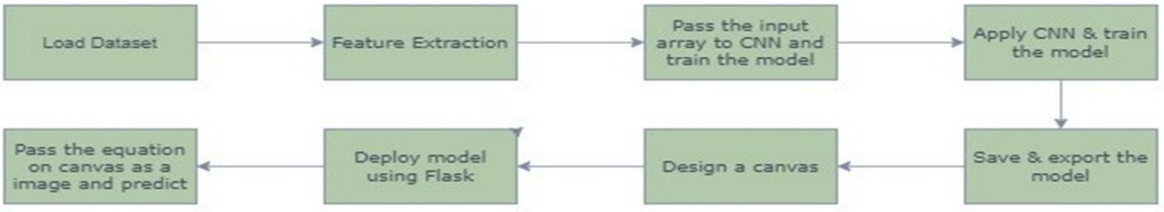

Fig. 1: Overall Flow Diagram

We have proposed a system that allows user to write the equation on the front end and the equation is identified and accordingly solved by using our trained model.

We first train the model to identify handwritten digits and mathematical symbols. After the equation is written on the canvas inthe frontend, we use find Contour function and bounding Rect function to bound each digit written in a rectangular frame.

Then each digit and symbol is passed to our model which we have trained using Convolutional Neural Network.

Detailed flow of Convolutional Neural Network and the output of the equation is described below.

A. Find Contours()

Contours can be explained as the curve joining all the continuous points, having same colour or intensity.

The contours are useful tool for shape analysis and object detection and recognition. So for our digit recognition we use rectangle shape for finding the digit. We do it using cv2. boundingRect() function.

There are two types of bounding rectangles:

1) Straight Bounding Rectangle

2) Rotated Rectangle

For our digit recognition we use Straight Bounding Rectangle as the digits are not rotated.

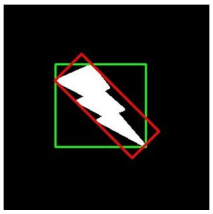

Fig. 2 Bounding Rectangle

B. Convolutional Neural Network (CNN)

The first step we do in CNN is to pass the pixels of the image in the form of an array to the input layer of the neural network.

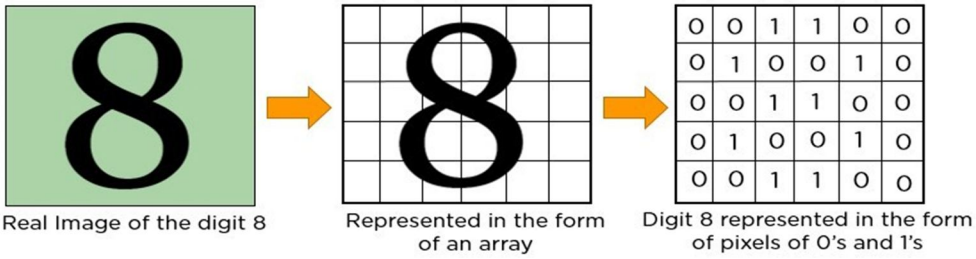

Fig. 3 Conversion of an image to array.

The hidden layers of the neural network carry out some feature extraction. There are multiple hidden layers such as Convolution layer, pooling layer and Relu layer. Also, there is an output layer that gives us the output.

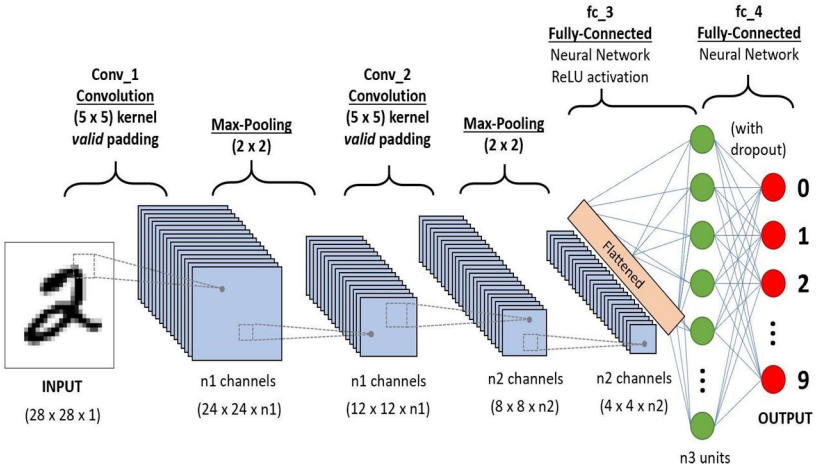

Fig.4 CNN Architecture to classify handwritten digits.

1) Convolution

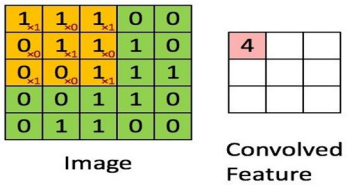

Fig. 5 Convolution

The reason we do convolution is that it helps us to extract some high level features such as edges from the input image.There is no limitation on the number of convolutional layers. We can add multiple convolutional layers according to our neural networks.

2) Max pooling

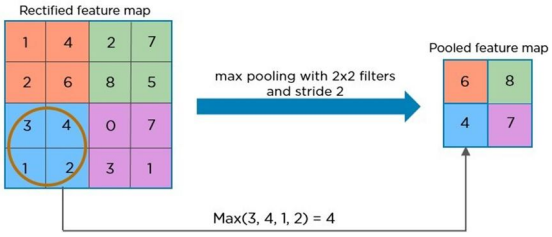

Fig. 6 Max pooling(2x2)

Pooling layer is responsible for reducing the size of the convoluted feature. As the computational power needed to process the data is quite high, thus we reduce it using the Pooling. Also, it is useful to determine the dominating features. Similarly like max pooling, we can also use average pooling which calculates the average of the given filters in the feature map. Maxpooling is also very helpful in removing the noise.

3) Flattening

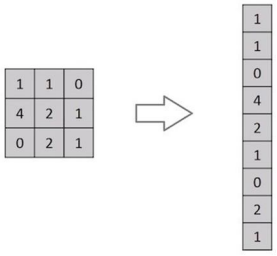

Fig. 7 Flattening of a 3x3 image matrix into a 9x1 vector

To pass the input to fully connected layer, we need to flatten the final output matrix we get after pooling. We flattenthe image into a column vector. The flattened output is fed to the Feed Forward Neural Network.

4) *Fully Connected Layers:* There are one or more fully connected layers at the end of convolutional neural networks. Their job is to perform classification based on the features extracted during convolutions. We use Rectified Linear Unit(ReLu) activation function to introduce non linearity. ReLu function is the default activation function of the Convolutional Neural Networks.

5) *ReLu:* In a neural network, the activation functions is responsible for transforming the summoned weighted input from the node into the activation of the node or output for the input. The rectified linear activation function or ReLu for short is a piecewise linear function that will output the inputdirectly if it is positive, otherwise, it will output zero. It has become the default activation funcion for many types of newural networks because a model that uses it is easier to train and often achieves better performance.

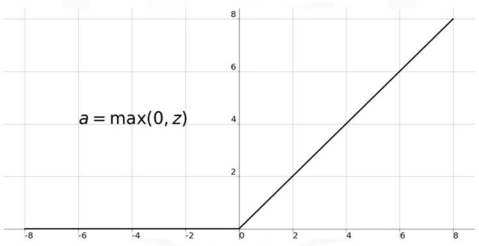

Fig. 8 ReLU function

6) Output Layer: The final fully connected layer uses the 'softmax' activation function which gives the result in terms of probability in between 0 to 1 for each of the output labels (0 to 9 and symbols such as +,-) that we are trying to predict.

7) *Softmax:* Softmax is a mathematical function that converts a vector of numbers into a vector of probabilities, where the probabilities of each value are proportional to the relative scale of each value in the vector.

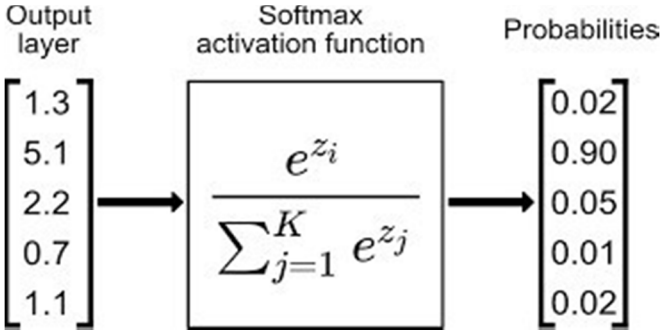

Fig. 9 Softmax Function

C. Libraries used

We have used Flask to deploy the model. Also various libraries and pre-processing techniques used are as follows :

1) *Opencv:* OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications

2) *Keras:* Keras is a deep learning API written in python, running on top of the machine learning platform TensorFlow. It was developed with a focus on enabling fast experimentation. Being able to go from idea to result as fast as possible is keyto doing good research.

3) *Tensorflow:* TensorFlow is a free and open-source software library for machine learning. It can be used across a range oftasks but has a particular focus on training and inference of deep neural networks. Tensorflow is a symbolic math library based on dataflow and differentiable programming. It is used for both research and production at Google.

D. Neural Network Training Parameters

Parameter	Value/Type
No of Layers	5
No of epochs	5
Activation Function	ReLU
Batch size	256
Input image size	(28,28,1)
Output Parameters	13
Output Activation Function	Softmax

Table 1 : Neural Network Training Parameters

IV. RESULT

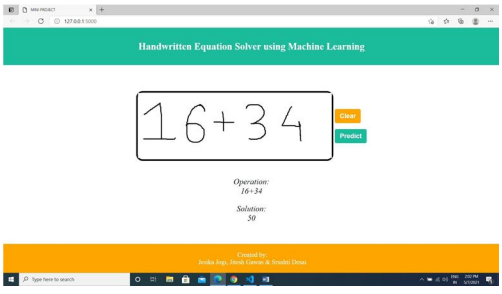

Fig. 10 Addition Operation

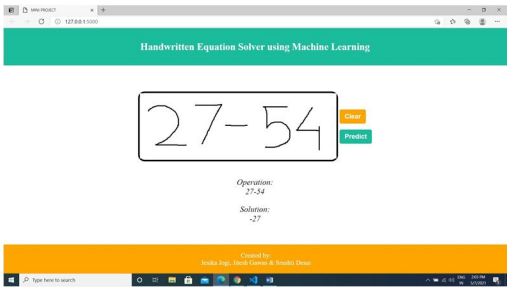

Fig. 11 Subtraction Operation

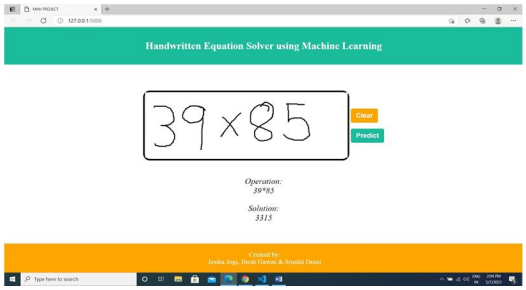

Fig. 11 Multiplication Operation

V. CONCLUSIONS

In this project, we put forth the idea of solving basic mathematical handwritten equations using Convolutional Neural Networks. When the user writes the equation on the canvas in the frontend, the equation on the canvas is converted into an image and passed onto the model to predict the digits and the mathematical symbols.

Also the system can further be expanded to solve complex engineering problems by training the model on more data on a powerful computer.

VI. ACKNOWLEDGMENT

We wish to express our sincere gratitude to Dr. Sanjay U. Bokade, Principal and Prof. S. P. Khachane, H.O.D of Department Computer Engineering of Rajiv Gandhi Institute of Technology for providing us an opportunity to do our project work on “Handwritten Equations Solver”. This project bears on the imprint of many people. We sincerely thank our project guide Mr.Dilip Dalagade for his guidance and encouragement in carrying out this synopsis work. Finally, we would like to thank our colleagues and friends who helped us in completing project work successfully.

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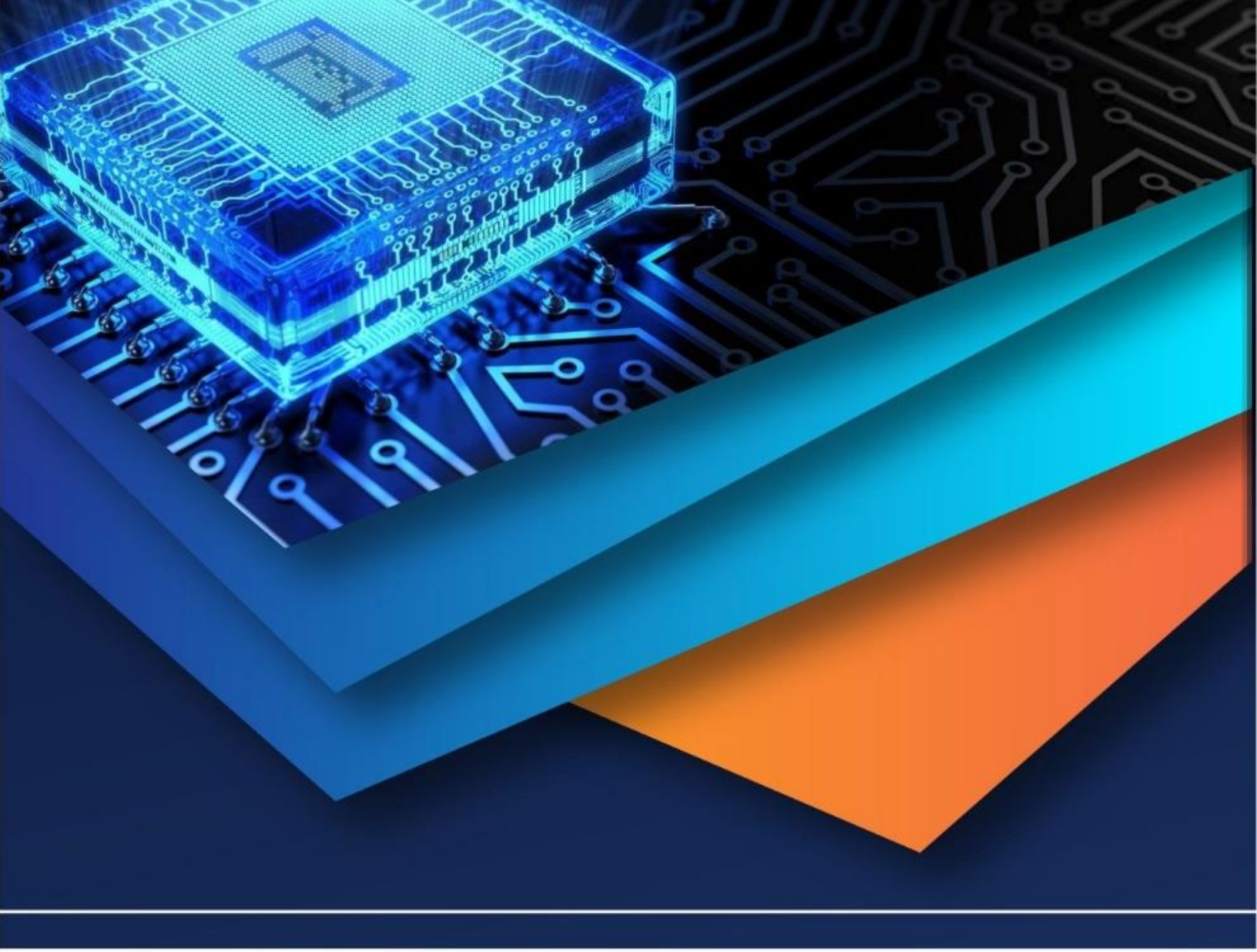

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