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Handwritten Equation Solver Using Convolutional Neural Network

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***Abstract*- At present, there is advancement in every sector of technology. Machine learning and deep learning technologies are important parts nowadays. Many fields such as artificial intelligence, handwritten recognition, robotics, and many uses these techniques. Convolution Neural Network is used for classification, image processing, and segmentation. In our project, we had developed a web application that solves handwritten equations. It captures handwritten equations via camera and the character recognition takes place through preprocessing of image. Segmentation along with the character classification is the most difficult part. Convolution Neural Network is used for classification of character that makes the equations as a string. String operations performed on each recognized equation for the solution. As based on earlier modules of equation solver, we have added a module that provides a link for each solution. Hence, our implemented model is easy to access to solve complicated equations, and get precise output.**

***Keywords*- Mathematical equations, Convolution Neural Network, Handwritten equations, Recognition, Segmentation, Character.**

I. INTRODUCTION

Mathematics is broadly used in almost all areas of science, such as physics, engineering, medicine, economics, etc. Digital document analysis and understanding is the major research concern today. For the recognition of English characters and numbers in electronic books OCR (optical character recognition) can attain higher recognition exactness.

Handwritten mathematical expression recognition is still a most challenging job to do in the area of computer vision. Due to the two dimensional nesting assembly and different sizes, the correction rate of symbol segmentation and recognition still cannot achieve its actual requirements.

The primary task for the recognition of mathematical expression is to segment the character and then classify those characters. Convolutional neural network (CNN) is one of the mostly used classification model in computer vision area.

In the last few years, deep Convolutional Neural Network (CNN) leaning has proved the outstanding performance in the field of image classification, machine learning and pattern recognition. Above all existing model, CNN is one of the most popular models and has been providing the state- of-the-art recognition accuracy on object recognition, human activity analysis, image super resolution, object detection, scene understanding, tracking, and image captioning. For the task of image classification CNN is outperforms above all the previous classification [7] method. CNN extract feature from the image by a series of operations.

In this project we consider a single handwritten quadratic equation in the form ay2+by+c=0 with any combination of its part. Our job is to recognize the handwritten quadratics from the image and for each successful detection finding the solution of that equation. Feature extraction of each individual character is most difficult part for any handwritten due to its different shape and structure.

To solve this problem we apply Convolutional neural network which doesn't required any predefined feature for classification of specific character. We use smallest number of hidden layer in order to reduce the training time with tolerable error rate.

II. LITERATURE SURVEY

Widad Jakjoud, Azzeddine Lazrek 'Segmentation method of offline Mathematical symbols', International Conference on Multimedia Computing and Systems (ICMCS), 2011[1]. The purpose of this paper is to detect, extract and segment the different symbols of mathematical expression. This expression will be recognized later.

Zouaoui Abderaouf 'license plate character segmentation based on horizontal projection and connected component analysis' 2014 world symposium on computer applications & research (wscar)[2].

In this paper, license plate segmentation system is proposed for Algerian vehicles. The proposed system is divided into two main parts: identification of the license plate from the input image and then segmented the characters from license plate.

Catherine Lu Karanveer Mohan 'Recognition of Online Handwritten Mathematical Expressions Using Convolutional Neural Networks' cs231n project report Stanford 2015[3]. We further investigate the problem of recognizing handwritten mathematical expressions, which we also chose for our CS221 final project

Pooja Kamavisdar, Sonam Saluja, Sonu Agrawal 'A Survey on Image Classification Approaches and Techniques' international Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 1, January 2013 [4]. This survey various classification techniques are considered; Artificial Neural Network (ANN), Decision Tree (DT), Support Vector Machine (SVM) and Fuzzy Classification

Nicholas E. Matsakis 'Recognition of Handwritten Mathematical Expressions' Massachusetts institute of technology may 1999[5].

In this, I will describe an on-line approach for converting a handwritten mathematical expression into an equivalent expression in a typesetting command language such as TEX or MathML, as well as a feedback-oriented user interface which can make errors more tolerable to the end user since they can be quickly corrected

III. IMPLEMENTED TECHNIQUE

In our implemented method at first data is been collected. After that we normalized the data. Normalizing has two parts, one is training data and other is testing data. Training data is then given to Convolution Neural Network, it consider each part of the image as a full image for further process.

For each line of equation image we then find specific characters in the form of connected component. Each segmented character is then providing as input to the Convolutional neural network model for classification of the character.

The resulting character that is the output of CNN is then used for making a character string which is similar to the original equation. These characters are then tested for accuracy. The prediction model predicts the solution which is then given as output.For each correct detection we finally find the solution of the quadratics. In Figure 1 block diagram of our implemented method is shown.

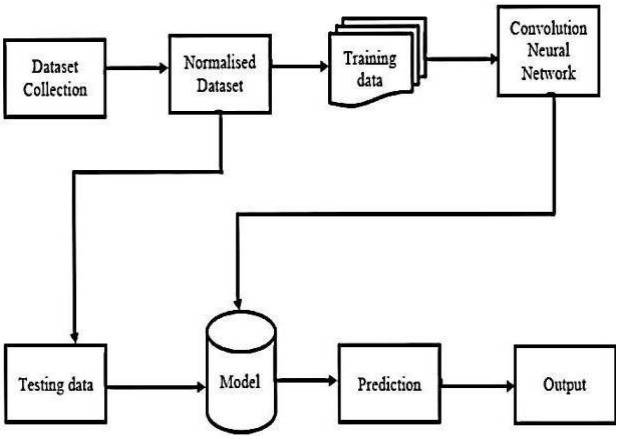

Fig 1. Block Diagram of Implemented System.

1. Dataset Preparations:
Preparation of the dataset is the fundamental concern for this work. Characters such as English digit, alphabet and mathematical symbol all can be well defined by their edges. For this reason we first prepare dataset as the most precedence given to its edges that is enlighten the edges.

We prepare some dataset by ourselves and we also used some modified version of NIST dataset which is similar as the popular MINIST dataset for digit. For each category we use 2000 data item for the training of the network. And most of the case our network training we gained more than 98.5% training accuracy. Image size we used in dataset is 32×32 gray level image.

2. Normalizing Dataset:
Normalization is a technique often applied as part of data preparation for machine learning. The goal of normalization is to change the values of numeric columns in the dataset to a common scale, without distorting differences in the ranges of values. For machine learning, every dataset does not require normalization. It is required only when features have different ranges.

3. Training Dataset:
The model is initially fit on a training dataset, which is a set of examples used to fit the parameters of the model. The model is trained on the training dataset using a supervised learning method, for example using optimization methods. In practice, the training dataset often consists of pairs of an input vector and the corresponding output vector, where the answer key is commonly denoted as the target.

The current model is run with the training dataset and produces a result, which is then compared with the target, for each input vector in the training dataset. Based on the result of the comparison and the specific learning algorithm being used, the parameters of the model are adjusted. The model fitting can include both variable selection and parameter estimation.

4. Convolution Neural Network:
A Convolutional Neural Network is a special type of an Artificial Intelligence implementation which uses a special mathematical matrix manipulation called the convolution operation to process data from the images.

5. Convolution:
A convolution does this by multiplying two matrices and yielding a third, smaller matrix. The Network takes an input image, and uses a filter (or kernel) to create a feature map describing the image.

In the convolution operation, we take a filter (usually 2x2 or 3x3 matrix) and slide it over the image matrix. The corresponding numbers in both matrices are multiplied and added to yield a single number describing that input space. This process is re peated all over the image. This can be seen in the following animation.

This is a 2-D representation of calculations happening in 3 dimensions. This is what is actually happening.

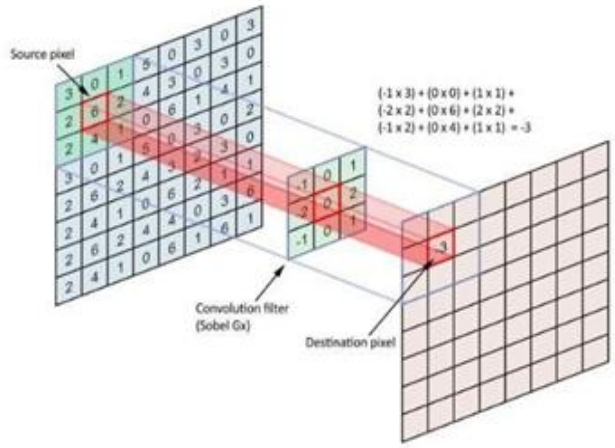

Fig 2. Convolution Neural Network.

We use different filters to pass over our inputs, and take all the feature maps; put them together as the final output of the Convolutional layer. We then pass the output of this layer through a non- linear activation function.

The most commonly used one is ReLU. The next step of our process involves further reducing the dimensionality of the data which will lower the computation power required for training this model. This is achieved by using a Pooling Layer.

The most commonly used one is max pooling which takes the maximum value in the window created by a filter. This significantly reduces the training time and preserves significant information.

6. Max Pooling:
Max Pooling is a convolution process where the Kernel extracts the maximum value of the area it convolves.

Max Pooling simply says to the Convolutional Neural Network that we will carry forward only that information, if that is the largest information available amplitude wise.

Max- pooling on a 4*4 channel using 2*2 kernel and a stride of 2: As we are convolving with a 2*2 Kernel. If we observe the first 2*2 set on which the kernel is focusing the channel have four values 8,3,4,7. Max-Pooling picks the maximum value from that set which is “8”.

Here in our context, we will make a kernel that amplifies the image of the cat’s eye to such an extent that even after Max Pooling the predominant information is not lost.

7. Test Data Set:
A test dataset is a dataset that is independent of the training dataset, but that follows the same probability distribution as the training dataset. If a model fit to the training dataset also fits the test dataset well, minimal over fitting has taken place (see figure below). A better fitting of the training dataset as opposed to the test dataset usually points to over fitting.

A test set is therefore a set of examples used only to assess the performance (i.e. generalization) of a fully specified classifier. To do this, the final model is used to predict classifications of examples in the test set. Those predictions are compared to the examples' true classifications to assess the model's accuracy.

8. Model:
A one-dimensional CNN is a CNN model that has a Convolutional hidden layer that operates over a 1D sequence. This is followed by perhaps a second Convolutional layer in some cases, such as very long input sequences, and then a pooling layer whose job it is to distill the output of the Convolutional layer to the most salient elements.

9. Prediction:
After the model is fit, we can use it to make a prediction. The model expects the input shape to be three-dimensional with [samples, timesteps, features], therefore, we must reshape the single input sample before making the prediction.We can tie all of this together and demonstrate how to develop a 1D CNN model for univariate time series forecasting and make a single prediction.

IV. EXPERIMENTAL RESULTS

This is our first user interface where users can browse or upload the input image (question) and gets step by step solution.

By clicking on browse files button user gets a device storage window from where user can upload the image (question).

Fig 3. Introduction.

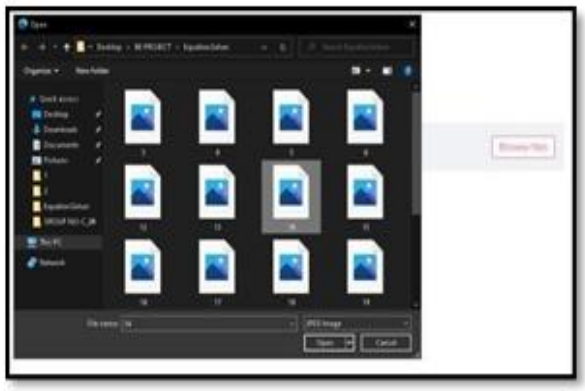

Fig 4. Process of uploading.

After uploading the image the user gets the step by step solution of the given question (Fig 4.3).

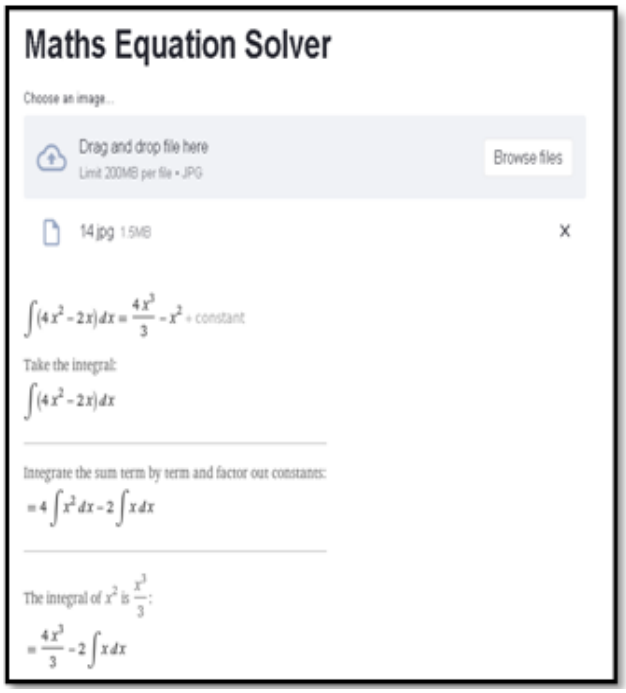

Fig 5. Step by step solution.

In our system user also gets the graphs of the uploaded question, as graphs helps user to get clear answer (Fig4.4).

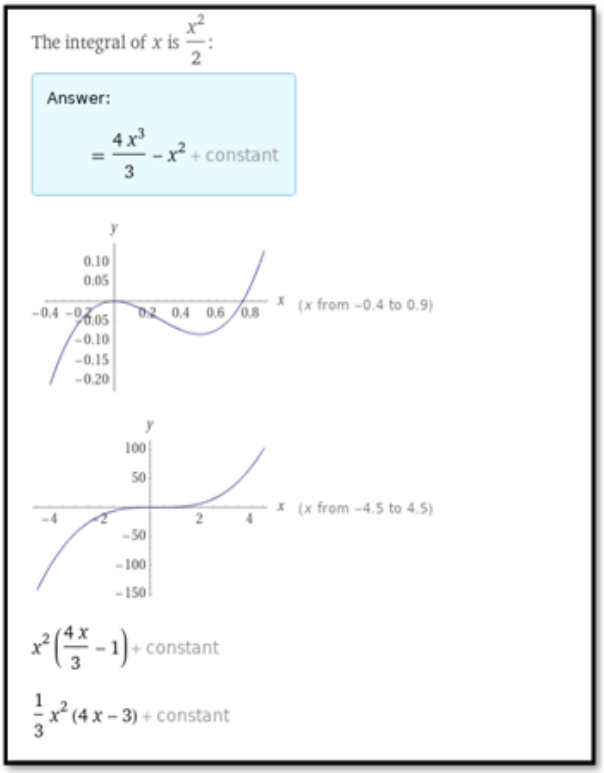

Fig 6. Graph.

Our project also suggests some reference links(Fig 4.5) of formula and the method used for solving, and some related questions to our uploaded question.

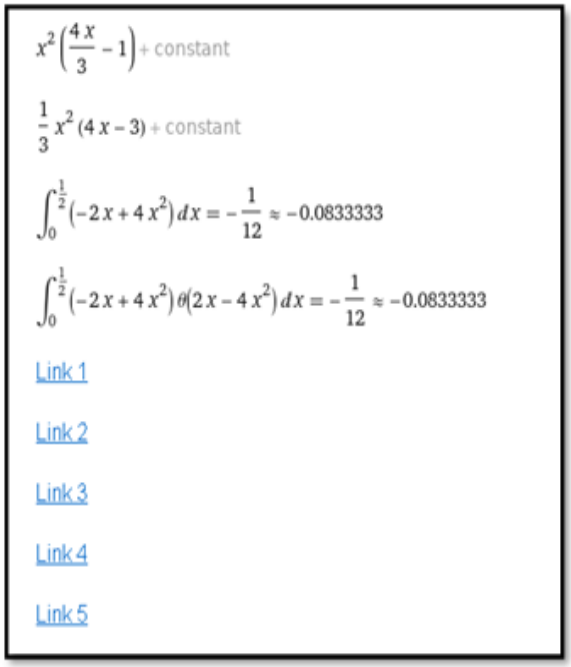

Fig 7. Reference Links.

User also gets some videos links where the user can check out how to solve the question (Fig 4.6) and some related questions to our uploaded question.

Fig 8. Video Link.

V. COMPARISION

Parameter	Existing System	Implemented System
Complex Numerical	In this system, complex numerical cannot be solved.	In our updatedsystem, complex numerical like Integration canbe solved.
Solution	In this systemwe do not getstep by step solution of given equation.	We get step bystep solution of given equation.
Links	Links for reference arenot available.	Links are available related questions.E.g.:- YouTube links.
Graphs	Solution for graphical equation is given withoutgraph.	Here graphs are providedfor graphical equation.

VI. CONCLUSION

We mainly focused on recognizing handwritten mathematical quadratics. We consider a single quadratics and also series of quadratics for the Recognition.In our system we can also solve complex numerical like integration. Convolutional neural network the most powerful classification model is used in the classification part. Once successful Recognition of the quadratic in any combination we further process the detected equation for finding the solution of the quadratic. Solution of quadratic equation will be given step by step along with the reference link at the end of the Solution.

REFERENCES

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[3] Catherine Lu Karanveer Mohan.' Recognition of Online Handwritten Mathematical Expressions Using Convolutional Neural Networks' cs231n project report Stanford 2015.
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[5] Nicholas E. Matsakis 'Recognition of Handwritten Mathematical Expressions' massachusetts institute of technology may 1999.