International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 07 | July 2022 www.irjet.net p-ISSN: 2395-0072

Generating LaTeX Code for Handwritten Mathematical Equations using Convolutional Neural Network

Aryan Sharma*, Ashwitha A Bhandary*, Harshit V Kaisare*, Saumya Semwal*, Prof Rakshith P

** These authors have contributed equally to the work*
Dept. of Computer Science Engineering, JSS Science & Technology University, Mysore, India - 570006

Abstract **–** *Handwritten mathematical equation recognition and processing are one of the complicated issues in the area of computer vision. Classification and segmentation of a single character makes it even harder. In this paper, Convolution Neural Network(CNN) is used for recognizing the equations as it provides better accuracy compared to other models like Support Vector Machine (SVM) and Artificial Neural Network (ANN). Furthermore, the obtained result is converted to LaTeX code which can be used for various scientific purposes.*

Key Words: **Convolutional Neural Network, Computer Vision, Support Vector Machine, Artificial Neural Network, LaTeX code.**

1. INTRODUCTION

Due to technological advancement, handwriting which was a natural part of human interaction is now slowly being replaced by a digital pen, stylus, interactive panels and smart writing surface. These are also been adopted in educational institutions and the workplace, which in turn results in the rise in demand of handwriting recognition which also involves the unique handwriting of each individual.

The outbreak of the COVID 19 pandemic increased the need for such applications for users and students. There was a sudden increase in the usage of handwritten interactive applications for the evaluations, which was used majorly in online and distance education modes. There also have been many advances made in sequence recognition models based on CNN.

Mathematical expressions play an important role in engineering, research, finance, education and other domains. The large set of mathematical symbols are often similar to one another, especially in handwritten expressions which causes few issues in recognition. The input which is the handwritten mathematical expression is often provided by the users through the keyboard or using any other input devices. Given equations will be character segmented and classified using the required technique and further will be returned as LaTex code. The proposed technology will be implemented to recognize a handwritten mathematical expression from an image and then solve it to produce the result, later converting it to its corresponding LaTex code.

2. LITERATURE SURVEY

2.1 Handwritten Character Recognition from Images using CNN-ECOC

Mayur Bhargab Bora, Dinthisrang Daimary, Khwairakpam Amitab, Debdatta Kandar, proposed a Convolutional Neural Network(CNN) - Error-Correcting Output Code (ECOC) approach, which is the hybridization of CNN architecture (used for feature extraction) and ECOC classifier (used for classification).

2.2 Recognition and Solution for Handwritten Equation Using Convolutional Neural Network

Md Bipul Hossain, Feroza Naznin, Y.A. Joarder, Md Zahidul Islam, Md Jashim Uddin, proposed a method to recognize the handwritten quadratics of the form $ay^2+by+c=0$ from the images. They found the correct solution, for each successful detection of the equations.

2.3 Identification of Handwritten Simple Mathematical Equation Based on SVM and Projection Histogram

Sanjay S. Gharde, Pallavi V. Baviskar, K. P. Adhiya, have proposed the following method to identify handwritten simple mathematical equations. Here the unwanted data like dots, loops, curves, and lines were removed from the images using a noise removal algorithm. They also used a projection histogram for feature extraction and for classifying the equations, they applied a Support vector machine algorithm.

2.4 Handwritten Equation Solver Using Convolutional Neural Network

Shweta V. Patil, Apurva S. Patil, Harshada C. Mokal, Asst. Prof. Mr Swapnil Waghmare developed a web application which captures handwritten equations via camera. Initially, the preprocessing of the images is performed. Then, character segmentation is done on the obtained output. Convolution Neural Network is used for the

classification of characters which then is converted to a string format. String operations are performed on each recognized equation for the solution. They have also provided the links which explain the solution in detail for each of the equations.

3. PROPOSED WORK

The dataset is collected from an online source. We have considered nearly 30,000 images for training, which consisted of various mathematical symbols. These images are used for training our CNN model. After our model is trained, we input an image containing a handwritten mathematical equation. The inputted image is then grey scaled and binarized so that it will be easy for the model to segment it. Then, the image is segmented and processed. It will be then converted to the corresponding LaTeX string.

We have created a simple web page on top of the model by using HTML, CSS and javascript. This allows the users to upload the images and retrieve the results.

We measured the output of our application with 78 manually picked handwritten equations from the im2LaTeX dataset. To measure the overall accuracy of the model, we used the average minimum edit distance and Character error rate(CER).

3.1 SYSTEM ARCHITECTURE

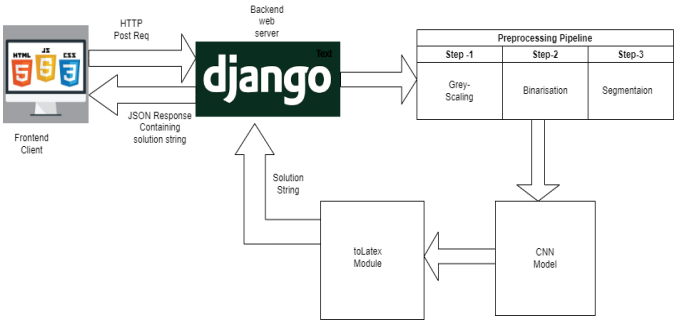

Figure 1 - Flow Chart

A. Pre-processing of Image – The objective of the pre-processing is to construct necessary information. Here, the inputted image is grey scaled and binarised. Then the image is segmented.

B. Neural network model – The above image is inputted to the Convolutional Neural Network (CNN) model, which was trained previously using the dataset containing handwritten mathematical symbols.

C. Conversion to LaTeX string - The output from the above step is converted into its corresponding LaTeX string by parsing the image from left to right. While the model parses each character, it starts building the expression tree. For every mathematical symbol parsing rules are defined, which changes the parsing direction accordingly. This is a recursive solution which evaluates each character and takes the decision based on the current character and what is on top of the stack, thus producing the required LaTeX string.

D. Displaying the solution –The output solution equation is displayed on our web page. We used django to interact with the backend server and fetch the results. It sends the Json response to the web page.

3.2 METHODOLOGY

3.2.1 Handwritten mathematical equation processing:

Data is selected from an online source i.e., https://www.kaggle.com/xainano/handwrittenmathsymbols. There were around 100,000 images and we have considered around 30,000 images for training. The resizing and formatting of data are handled here.

Images are converted to Grayscale and represented through a single matrix because detecting characters on a coloured image is more challenging than on a

grayscale image. If the grey bitmap is Y and the colour bitmap is R, G and B, then the formula is Y = 0.299R + 0.587G + 0.114B.

Binarization is the procedure of choosing a threshold value for the adaptation of pixel values into 0's and 1's where 1's represent the black pixels while 0's represent the white pixels. The threshold choice of binarization can be approved in two ways: overall threshold and partial threshold.

Then the segmentation of the binarized image is done. The dataset is trained and then the input images will be classified into a particular class. Finally, the model will solve the equations and generate the corresponding LaTeX string.

3.2.2 Web application

A simple front end is created so that the user can upload the images containing handwritten mathematical equations to it.

The equation will be then processed and later converted to its corresponding LaTeX code, which will be displayed on our web page.

4. RESULTS

4.1 Comparison of accuracies of various models :

We took the dataset which consisted of handwritten mathematical symbols from kaggle i.e., https://www.kaggle.com/xainano/handwrittenmathsymbols. We applied a few of the models like SVM, CNN, ANN to classify it. We got the accuracy as shown below.

Sl No.	Model Name	Accuracy (in %)
1	Convolutional Neural Network	99.00
2	Support Vector Machine	98.95
3	Artificial Neural Network	95.85

4.2 Handwritten mathematical equation processing and LaTeX code generation using CNN:

4.2.1 Handwritten mathematical equation processing :

Step 1: Handwritten mathematical equation is the input given to the model.

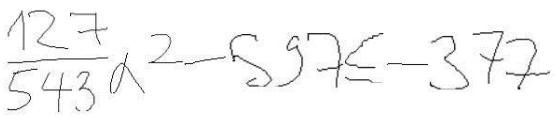

Figure 2 - Input: handwritten mathematical equation

Step 2: The input image is grey scaled and binarized so that it will be easy for the model to segment it.

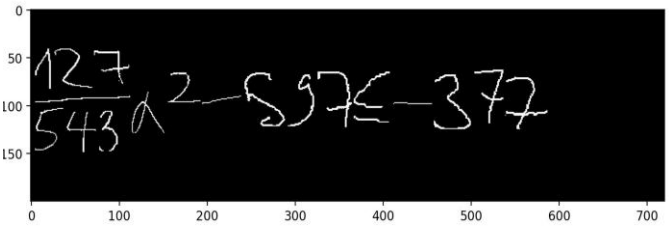

Figure 3 - Grey scaling and Binarization

Step 3: The above-binarized image is then segmented as shown below.

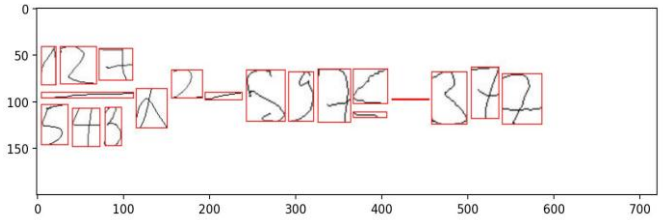

Figure 4 - Segmentation of the binarized image

Step 4: The equation is processed and converted to its equivalent LaTeX string.

Figure 5 - Producing the LaTeX string

'\' is the symbol that sits according to the LaTeX syntax. The '\' symbol was producing some errors while performing some string operations, as it acted as the escape character. We have replaced '\' with '#'.

In the final output, this issue has been resolved.

4.2.2 Web application

Frond end: A simple web page is created on top of the model by using HTML, CSS and javascript. This allows the users to upload the images and retrieve the results.

Here, we can observe that '#' which was used while producing the LaTeX string has been replaced with '\', thus producing an acceptable result.

Metrics:

```
Total input lines -->78

average min edit distance -->2.3333333333333335

average cer -->6.6667922576286145
```

We measured the output of our application with 78 manually picked handwritten equations from the im2LaTeX dataset. We got an average minimum edit distance of 2.33 and an average character error rate (CER) of 6.67.

5. CONCLUSIONS AND FUTURE ENHANCEMENT

Handwritten mathematical equation processing is one of the most interesting and difficult fields. The processing of the equations is tedious and it requires a lot of attention because of the variations in handwriting. As mentioned above, CNN model produced higher accuracy. Since there is a growing popularity for the use of CNN among the practitioners for image recognition related activities, we decided to go ahead with this model.

Currently, limited mathematical symbols have been introduced for our project, to reduce the complexity. In the future, we can also include many other mathematical symbols and equations involving integration, differentiation etc. With further time and computational resources, there can be an increase in expression accuracy obtained.

ACKNOWLEDGEMENT

It gives us immense pleasure to write an acknowledgement to this project, a contribution of all the people who helped to realize it. We extend our deep regards to Dr S.B. Kivade, Honorable Principal of JSS Science and Technology University, for providing an excellent environment for our education and for his encouragement throughout our stay in college. We would like to convey our heartfelt thanks to our HOD, Dr Srinath, for giving us the opportunity to embark on this topic. We would like to thank our project guide, Prof. Rakshith P for their invaluable guidance and enthusiastic assistance and for providing us support and constructive suggestions for the betterment of the project, without which this project would not have been possible. We appreciate the timely help and kind cooperation of our lecturers, other staff members of the department and our seniors, with whom we have come up all the way during our project work without whose support this project would not have been a success. Finally, we would like to thank our friends for providing numerous insightful suggestions. We also convey our sincere thanks to all those who have contributed to this learning opportunity at every step of this project.

REFERENCES

[1] Mayur Bharag Bora, Dinthisrang Daimry, Khwairakpam Amitab,Debdatta Kandar,Handwritten Character Recognition from Images using CNN-ECOS.

[2] Md Bipul Hossain, Feroza Naznin, Y.A. Joarder, Md Zahidul Islam, Md Jashim Uddin,Recognition and solution for handwritten equation using CNN.

[3] Sanjay S. Gharde, Pallavi V. Baviskar, K. P. Adhiya,Identification of Handwritten Simple Mathematical Equations based on SVM and Projection Histogram.

[4] Shweta V. Patil, Apurva S. Patil, Harshada C. Mokal, Asst. Prof. Mr Swapnil Waghmar,Handwritten Equation Solver using Convolutional Neural Network.

BIOGRAPHIES

Prof. Rakshith
Professor at JSS Science & Technology University,
Dept. of Computer Science Engineering

Aryan Sharma
Student of JSS Science & Technology University,
Dept. of Computer Science Engineering

Ashwitha A Bhandary
Student of JSS Science & Technology University,
Dept. of Computer Science Engineering

Harshit V Kaisare
Student of JSS Science & Technology University,
Dept. of Computer Science Engineering

Saumya Semwal
Student of JSS Science & Technology University,
Dept. of Computer Science Engineering