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Bangla Handwritten Math Recognition and Simplification Using Convolutional Neural Network

Fuad Hasan, Shifat Nayme Shuvo, Sheikh Abujar, and Syed Akhter Hossain

Abstract Mathematical simplification—it is an interior capability in human, but machine does not have cognitional skills that can understand the problem by visual context. In this present work, we represent a new system which takes an input image of Bangla handwritten mathematical expression and automatically simplifies the problem and generates the answer as an output. Proposed pursuit can be workable in an embedded system as well as mobile application. In this scope for recognition purpose, we use a CNN model called MatheNET for segmented Bangla digits and mathematical symbols. This model dataset contains 54 classes, 10 numerals and 44 mathematical operators and symbols. The algorithm has followed for rising a system model for automatically Bangla handwritten math simplification; it has been done really good job. In the fields of the state of the art, contributions in Bangla languages are still very low. Developing an automatic math equation solver has been a desire of the researchers who worked in the field of NLP for many years.

Keywords Bangla handwritten equation · Simplification · Prepossessing · Segmentation · Implementation · CNN · Mathematical expressions · Recognition · Image processing

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1 Introduction

The effectiveness of mathematics in human life and natural science is like a bless of God. All places of science like physics, electronics, banking, engineering are stands with the influence of mathematics. Nowadays, handwritten mathematical equation and expressions recognition and solving with the help of AI is supreme area in scientific research. About more than 250 million scientific documents are written in Bangla. Recognition of handwritten mathematical operators or symbols is still more difficult job due to segmentation of character symbols of math. Math expressions contains different sizes and two-dimensional symposium. The main part of this work is segmentation to the sequence of the expression and through the recognition process simplify the math and show the output to the user in Bangla and English both languages. For solving a problem.

The study of basic neural machine translation (NMT) research consists of encoder–decoder, in which encoder takes the vector form of words as input to process and decoder uses the vector to predict the most likely output. To get the maximum performance of the translation output, NMT model jointly learns the parameters [1–3] with minimum domain knowledge. However, NMT has limitation to deal with the long sentences [4]. However, compare to resource-rich languages, the development of MT systems is very sparse for the Bangla–English language pair. The literatures also report that the development of large-scale parallel corpus for Bangla–English is very scarce.

Human use many cognitive abilities. From segmented image classification is done by using a CNN model. CNN eliminated property from the image by a sequence of actions. By the help of the CNN model after successfully recognizing each of the segmented digits and operators, we perform a string operation to calculate those expressions.

The structure of this paper is as follows. Section 2 provides a brief overview of the existing work on mathematical equation recognition. Sections 3 and 4 represent the approaches that are used in this system. Following that in Sect. 5, we discuss about how we solve the expressions. After that, in Sect. 6, we discuss about the results of this work and at last conclude the whole work in the last section.

2 Literature Review

There can be found various paper on handwritten character segmentation [1, 4] for Bangla languages as well as other languages. Some scheme is also working on mathematical expressions recognition "MER." This are very few of amount and not properly work out in Bangla language. Like "Using SVM and projection histogram identification of ME" have mentioned in [5]. Few are effective for offline printed mathematical expressions and recognition mentioned by Zanibbi et al. (2002), "Recognition of printed mathematical symbols" [6], "Using SVM mathematical

symbols identification" [7], "Recognition of online mathematical symbols using template matching distance" [2], "Offline handwritten mathematical symbols recognition using character geometry" [3]. This all proposed method for recognition of symbols and segmentation using various actions. Recognition has been also done by CNN-based model for mathematical symbols and character [8, 9]. Some discussion about concerned to the labyrinth of online mathematical expression recognition [10]. Majority of those paper concentrated in the recognition scheme.

In this approach, the main focus is on Bangla handwritten expression simplify, as there is not any proper work which can successfully handle the problem. For Bangla handwritten image after preprocessing, segmentation and recognition of the input image, generating a string from that expression and simplification of that expression is the main target.

3 Methodology

In this activity, for identifying handwritten mathematical expressions and simplifying the problem, we illustrated many different phases from taking an input image to final result that are described below. Figure 1 shows the workflow diagram of our methodology.

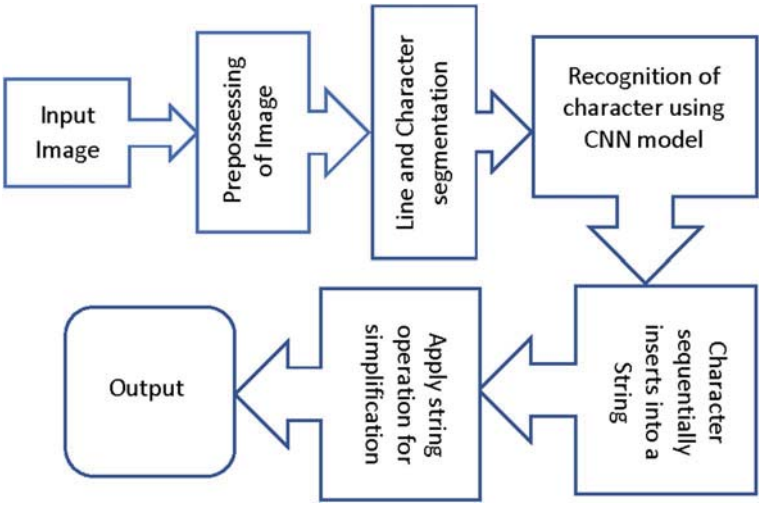


Fig. 1 Workflow diagram

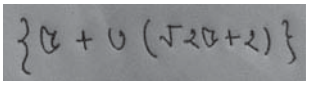


Fig. 2 Input image

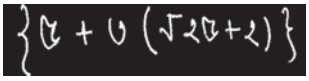


Fig. 3 After preprocessing

3.1 Preprocessing

Preprocessing is the method in which we transform and modify the input image to make it suitable quality for the recognition purpose. At first, we transform the original input image into grayscale image cause in color image the identification of character is more challenging andhen remove some noise from the grayscale image. At last, we turn the image into BINARY_INV. This method changes all the pixel value 0–255. This will reduce our computational time for segmentation, eliminating all the unnecessary pixel value as much as allowable. Figures. 2 and 3 show the input image and preprocessed image.

3.2 Line Segmentation

In an image, there will be multiline of characters. Thus, by applying text line segmentation on an image can be identified is there multiple handwritten expressions exits or not. Each line consists of minimum horizontal gap between two lines. By iteration through horizontally in the image, if the pixel value is 255 (white pixel), it means it is a text. White pixel value of 255 is considered as a text. If the sum of horizontal row is 0, it means it is a black row, and it is considered as a gap between two lines. Line segmentation has been done in many languages [11] and earn massive achievement. Figure 4 shows the line detection of preprocessed image.

Fig. 4 Line detection

Fig. 5 Denoting character region

Fig. 6 Segmented character

3.3 Character Segmentation

Segmentation of a character is an established way to extract an image to sequence of character into individual images [12]. As the preprocessed image have only binary pixel values, calculate the summation of all pixels from each column in the image. If the resulting sum of each column is inferior or equal to five (binary image black pixel value 0), then it is called a gap and suspect as a character. So, the idea is in y axis connected white pixel is considerable as a separate character shown in Fig. 5. After finding the gaps between each character, it is easy to remove the unnecessary vertical and horizontal gaps from the image. Then, each character is separated using by this method [4]. Finally, resize the separated image into pixel size of (28×28). Figure 6 shows the segmented characters.

4 Classification and Recognition

In this paper, we use CNN model for recognition and classification purpose. MathNET [13] model contains total 54 classes in which 10 are Bangla numerals and 44 mathematical symbols and operator. This model dataset contains 32,400 images. The recognition accuracy of this model is 96.50%. Here too, this is the most obtained accuracy for handwritten Bangla math recognition. (28×28) pixel binary_inv images are used for an input layer in training and testing session of the model. Figure 7 shows the architecture of MathNET.

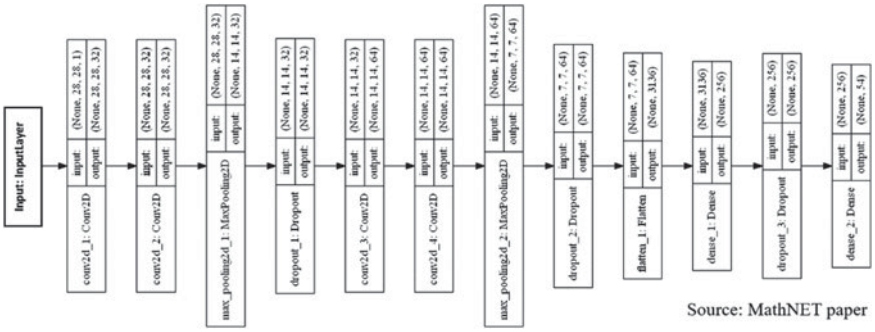


Fig. 7 Architecture of MathNET [13]

Table 1 Some samples of mathematical expressions covered

Area	Expression input image	Output
add	৪৭ + ৫০	৯৭
sub	৭৮৯ - ৪৫৬	৩৩৩
mul	৯৮ × ৪০	৩৯২০
div	১০২ ÷ ৫	২০.৪০
comparison	৭৮৯ > ৫০	সত্যি
sqrt	√২৫ + ৩	৮
Decimal mixed	৭৯.২৫ + (২০.৪৫ × ৫.৭ ৮)	১৯৭.৪৫১
percentage	১০০ × (২০ %)	২০
mixed	{ ৫ - ৩ × (১০ ÷ ২) }	-১০

5 Solution of Expressions

For each segmented numerals and symbols from the main image, we predict sequentially one by one and store the output sequentially into a list. After that, we convert the list into a string. Then, we perform string operation with the help of Python eval [14] function. Finally, we showed the output in Bangla and English, both languages. Table 1 shows some sample of expressions covered.

6 Experimental Result

Very few test images which are segmented from the input image are falsely recognized. The whole result depends on the recognition module. If one symbol or digit is falsely identified, the simplification result will be wrong. We test thousands of expressions, and some of the segmented characters are recognized falsely and give

wrong answer of the math. In most of the cases, almost 98% images are recognized correctly and give the correct answer, visualize in Fig. 8.

Table 2 shows some correctly recognized expressions and gives the correct answer.

Table 3 shows some falsely identifying symbols which cause the wrong answer of the math.

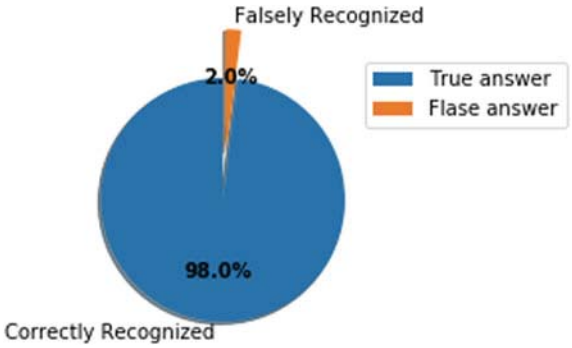


Fig. 8 Visualization of recognition rate

Table 2 Table II correctly recognized expressions

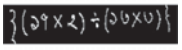
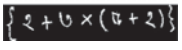
No	Input image	Truly recognized expression in String	True answer
1		{৫+৩×(√২৫+২)}	২৬
2		{(১৭×২)÷(১৩×৩)}	০.৮৭১৭৯
3		{২+৩×(৫+২)}	২৩

Table 3 Shows the error recognition of segmented character

No	Input image	Wrong recognized expression in String	True answer	False answer
1		(৫ + ৩ ১	৮	৩৬
2		২ ০ ১ + ৩	৫.১	২০৪
3		১৮) ৭	সত্যি	১৮৭

Sometimes human made mistakes too. In this example, input images do not clear; in image number 1, 2, and 3, the 1st closing bracket seems like Bangla 1, decimal point seems like 0, and comparison symbol seems like 1, respectively.

7 Conclusion and Future Work

In this presence, Bangla handwritten mathematical expressions simplification is described. For simplification of the math, the main part is done in the feature extraction from the image and recognition by the help of CNN model. If the CNN model classifies correctly all of the segmented images, then this will perform better in the simplification part. Simplification is done by string operations. At last, we successfully acquired the state-of-the-art representation in the recognition and simplification stage.

In next days, the focus will be to try to raise the precision level and also try to create a scheme feasible for composite mathematical equation at one time.

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