Classification of Mathematical Expressions for Visually Impaired People

Zahra ASEBRIY
Dept of Applied Mathematics and Computer Science Laboratory (LAMAI), Cadi Ayyad University, Marrakesh, Morocco

Said RAGHAY
Dept of Applied Mathematics and Computer Science Laboratory (LAMAI), Cadi Ayyad University, Marrakesh, Morocco

Omar BENCHAREF
SAEED, Higher School of Technology, Cadi Ayyad University, Essaouira, Morocco

Summary
Visually impaired people, face many problems to communicate and to study electronical scientific documents especially those containing mathematics expressions. To provide solutions in this topic, we propose an assistive system to help blind people to categorize mathematical formulas from electronical documents. The system acts on four steps: first the translation of query math formula into Presentation MathML code, and then we extract the structural and semantic meaning from the MathML expressions. In the classification phase, we used a deep learning as Recurrent Neural Network algorithm to classify the category of the query mathematical expression. Finally, the query result that is the category of mathematical formula is transformed into Braille code. Experiments were done using an experimental dataset composed of 1120 math expressions.

Key words:
Braille code; MathML; Deep learning; Translator Braille;

1. Introduction

Visually impaired people are an integral part of the society and they have all rights like sighted people to use computing technology for reading, writing documents, communicating with others, and searching information on the Internet. However, their disabilities have made them barriers of all types than the people with clear vision. Obviously, visually impaired need software solutions and assistive technologies which empower them to communicate easily using computer technology or internet. These systems were based on hearing sense and or touch reading. On this way, the famous systems developed to wrestle these disabilities are Braille code system.

Braille is based on touching used by blind people for communication and contact with the outside world (show figure 1). This system is not a language, it is just a code in which text can be written or read. However, it presents some limitations in translating all types of information like mathematical notations. Mathematical expression is not easy to be convey into braille or screen readers because it uses two dimensional writing while braille code –as normal text- is one dimensional writing. In order to simulate the two dimensional aspect of mathematical symbols, braille system needs to use Mathematical Markup Language such as Latex and MathML to linearize the representation of mathematical expression to translating encoded into Braille code.

MathML is a W3C recommendation, it provides a low-level specification for describing mathematics on the web or on the digits libraries and it can be rendered with many standard web browsers. Blind people can search or communicate their work in math through web, additional they may benefit to high quality educational software.

Contrary to mathematical mainstream notation, the mathematical Braille notation is not international. There are many mathematical Braille notations for example:

- Nemeth [1]: Used mainly in the North America, but it is also accepted in other countries such as India, and Malaysia.
- RNIB [2]: Used in the United Kingdom
- Marburg: Used in Germany, Austria and Poland
- CMU (Unified Mathematical Code): The math standard Spanish Braille for Latin America and Spain.

The aim of this work is to give an assistive technology for visually impaired people to classify the category of mathematical expressions from the electronical documents or webpages. The rest of the paper starts with a brief summary of the related work in section 2. Section 3 presents our proposed system of classification of category of math expressions. Section 4 discusses the results of our system. Finally, the conclusion presented in section 5.

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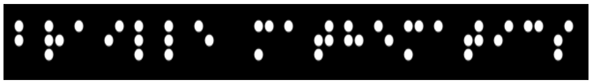

Fig. 1 Example of text in Braille code meaning "Braille Mathematics"

2. Related work

Visually impaired people need software solutions and assistive technologies which help them to communicate and exchange freely and widely their work on math using computer technology or internet. Currently, there are several systems based on hearing sense and or touch reading that allow mathematical expressions to be navigated and spoken.

S. Samuel et al. [3] proposed software based on two frameworks essentials. The first transformed content MathML into Nemeth Braille for visually impaired users who may access the braille output by means of refreshable braille devices or other tactile printing methods. The second framework can be used to create content MathML using a QWERTY keyboard for sighted people and using a braille keyboard for blind people. This software can allow a sighted user to communicate mathematics online and in real time with visually impaired Nemeth braille users.

Software solution described in [4] allows a sighted people to enter the math statement into Third Party Math Editor [5][6] and save it in the MathML format. This translation is carried out in two phases: the translation of the MathML elements into Nemeth Braille Code, then the implementation of irrelevant rules specific to Nemeth braille to MathML.

This paper [7] described a prototype to convert MathML algebraic expressions into two types of representation: 1) linear representation in an ASCII Braille file ready for embossing using CMU. 2) Navigable hierarchical representation of equations that allows collapsing and expanding branches [8][9]. This prototype is limited to algebraic equations and it still requires testing with final users.

Braille Math Extension to RoboBraille (BMER) [10] regrouped several Braille transcription and math conversion Libraries (Sensus SB4 [11], LibLouis [12], UMCL [13], fMath [14]) into single solution enabling blind users or others to mix and match amongst supported braille codes and braille math regimes. In this paper, the authors were selected four libraries to achieve the text and math conversions. They used Sensus SB4 and LibLouis for literary braille conversions of text, and fMath and UMCL handle conversions from MathML to variety of math braille codes.

3. System of classification of category of math expressions

Studying scientific electronical documents especially from electronical documents have always been a difficult task for visually impaired people. Blind people need software solutions to help them to read and study, easily and independently to others, using computer technology. In this paper, we proposed an assistive technology for blind student for classifying categories of math formulae from electronical documents. Figure 2 presents our proposed system. It is divided into four stages:

- Conversion mathematical expression into MathML
- Extraction features
- Classification
- Translation into Braille code

3.1 Conversion mathematical expression into MathML code

The goal of this phase is to identify and convert mathematical expressions from electronical document into uniform and standard format like MathML and Latex. MathML is a W3C recommendation which defines two Markups for representing math expression: Presentation and Content MathML. In this paper we used Presentation MathML shown as example in figure 3.

3.2 Features extraction

Extraction process is a crucial phase in our system for classification of category of mathematical expressions for blind people. In this phase we extracted the structural and semantic information from MathML code. The Method of extraction is based on calculation the number of occurrence of operators (+,-,*, /), constants, variables and functions and stored in the line features vector.

As example of math formula $z^2 - \sqrt{\frac{6}{z+1}}z + z$, we have: four operators: Plus defined by <mo>+, minus defined by <mo>- and invisible multiplication, three constants (2,6,1), one variable defined by <mi>z, the power function defined by <msup>, the square root function defined by <msqrt>, and the fraction function defined by <mfrac>. The line features vector in this case is:

Vl(3,1,1,2,1,1,1,0,0,0,0,0,0,0,1,0,0,0,0)

Other example, the line features vector of $1-\ln(\sqrt{a}+2)$ is:

Vl(2,1,0,1,1,0,1,1,0,0,0,0,1,0,0,0,0,0,0)

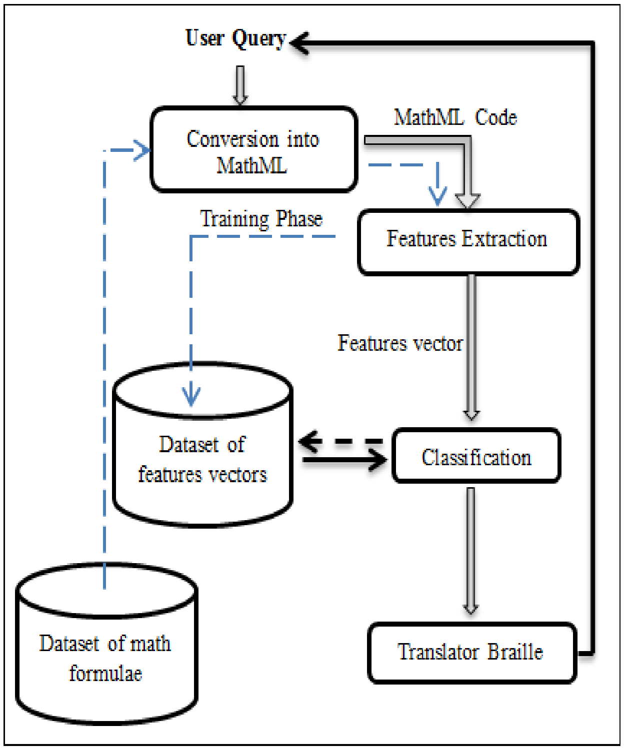

Fig. 1. Proposed System

3.3 Classification

To classify a category of query math selected by visually impaired people, we proposed to use in this phase Recurrent Neural Networks (RNNs) which is deep learning models that is becoming increasingly popular. It is a special type of neural networks which designed for sequence problems. It can be trained using backpropagation through time which is an algorithm for training supervised feed-forward neural network.

The aim of this training is to provide on the output neurons the desired values by minimizing a cost function which is defined as a Summed Squared Error (SSE):

$$C=\frac{1}{2}\sum_{p}^{n}\sum_{k}^{o}\left(d_{pk}-y_{pk}\right)^{2}$$

Where d is the desired output

y is the output of RNNs

```
<math>
  <msup>
    <mi>z</mi>
    <mn>2</mn>
  </msup>
    <mo>-</mo>
    <msqrt>
      <mrow>
      <mfrac>
        <mn>6</mn>
        <mrow>
          <mi>z</mi><mo>+</mo><mn>1</mn>
        </mrow>
      </mfrac>
      </mrow>
   </msqrt><mi>z</mi>
      <mo>+</mo><mi>z</mi>
</math>
```

Fig. 2. Presentation MathML $z^{2}-\sqrt{\frac{6}{z+1}}z+z$

3.4 Translation to Braille code

The result obtained in the previous phase was converted into Braille code. There are many translators that can make this conversion easily. In this paper we used a Braille translator to convert automatically the category of the query expression obtained during the classification phase. The figure 4 shows an example of this result.

Fig. 3. Example of result of conversion of text into Braille code meaning "logarithm equation"

4. Experimental Results

To evaluate the proposed system, we created dataset of mathematical expressions using equation editor MathType. This editor permits to convert easily these expressions into presentation MathML. We have created 1120 math equations divided into 7 categories: polynomial, logarithm, exponential, trigonometric, fraction, algebraic, and integral equations. Figure 5 present a Recurrent Neural Network of our system. We carried out tests to properly configure our network and we found these parameters: 8 neurons in one hidden layers and 0.005 for threshold terms. The error of this network is: 0.001061

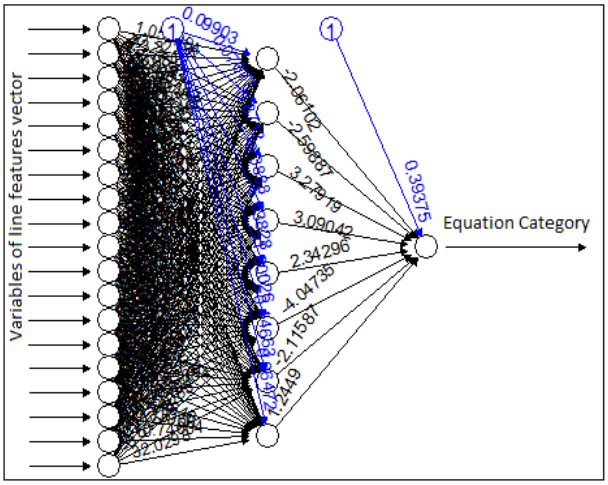

Fig. 4. Recurrent Neural Network of the proposed system

The mean square error (figure 6) in the phase the test of RNNs shows the best result.

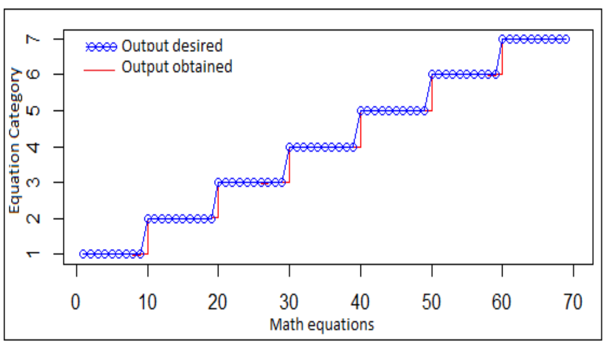

Fig. 5. Mean Square Error of RNNs

The error between output desired and output obtained is due to mathematical expressions which containing several functions categories for example math expressions:

$$1+\frac{1}{\sqrt{x+1}}+\frac{1}{\sqrt{y+1}}$$ is polynomial and fraction function

$$\log(\frac{\sin(a+b)}{a+b})$$ is logarithmic of a trigonometric function

The diversification and the introduction of new hybrid categories of two or more categories in the system can reduce this error.

This assistive technology is only a preliminary work to empower and help visually impaired students to use easily the internet or electronic documents to read and / or study math independently of others.

5. Conclusion

People with special needs, are waiting for more attention from the scientific community. Visually impaired people can increase their productivity with a small automatic assistance.

In this paper we propose a classification of category of mathematical expressions system adapted for Braille code users. In future, the inputs and outputs of the proposed system will be used by an E-learning Platform for visually impaired people.

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First Author: Zahra ASEBRIY
Phd Student at departement of department of Applied Mathematics and Computer Science, Faculty of Sciences and Technics, Cadi Ayyad University, Marrakesh, Morocco

Second Author: Said RAGHAY
Professor and director of the laboratory LAMAI at Faculty of Sciences and Technics, Cadi Ayyad University, Marrakesh, Morocco

Third Author: Omar BENCHAREF
Professor at Higher School of Technology, Essaouira, Cadi Ayyad University, Marrakesh, Morocco,