

# Mathematical word problem categorization using Machine Learning

Basanti Pal Nandi\*<sup>1</sup>, Poonam Ahuja Narang\*<sup>2</sup>

\*<sup>1</sup>CSE, Guru Tegh Bahdur Institute of Technology, New Delhi, Delhi, India

<sup>2</sup>CSE, Guru Tegh Bahdur Institute of Technology, New Delhi, Delhi, India

## ABSTRACT

Text categorization is a fundamental processing of Natural Language task. Mathematical word problem has a wide variety of classes to categorize, for the further processing of word problems. The classification of word problems plays an important role for text categorization, prediction of algebraic equation for a particular problem in the segment. Word problem classification will be a step towards word problem solving automatically. In this paper comparison of machine learning classifiers such as SVM, Decision Tree, k-Nearest Neighbour, Neural Network and Convolutional Neural Network are used for classification of four types of mathematical problems taking from elementary grade level. Addition, Subtraction, Multiplication and Division problems are the categories chosen from class 3 and class 4 mathematics workbook.

**Keywords:** Word Problem, Deep Learning, Machine Learning

## I. INTRODUCTION

Solving mathematical word problem is a long standing area of Artificial Intelligence. Word problem has numerous categories to look into. Not only Mathematics, problem described by Natural Languages is an integral part of Physics, Chemistry, Mechanics, Economics and as well as in the field of Engineering. Approaches towards automatically solving natural language problems have been explored since 40 years, whereas a deep evolution has not been made towards difficult problems as well as different natural language problems in a same module. If we want to solve diverse problems in a same machine we need to classify the problems for the machine understanding towards solution. The need for categorization of problems lies in this fact. Work on text categorization using machine learning is a much explored area whereas categorization of mathematical word problem are addressed in only a few paper. Machine learning algorithms have been used and tested on available databases of text processing, statistical approaches are also been used much. Binary classification and Multiclass classification are been compared with machine learning and statistical methods. Bio Inspired

and Evolutionary Algorithms are recent trends which are widely used in image classification, sentiment analysis and in text categorization. As there are no standard databases available for word problems of various categories, the classification results are not available for this domain. Here a database of 100 word problems has been created having 4 basic classes like addition, subtraction, multiplication and division. The benefit of such classification is to save the problems in correct category for tutoring system.

*Example 1: Ned rode his bike 7 miles to the library. He took a shortcut on the way home which was only 5 miles long. How many miles did Ned ride altogether?*

*Example 2: 15 children watched the circus. 8 children were holding banners. How many children were not holding banners?*

*Example 3: Mary goes fishing with Benny. Mary catches 6 trout. Benny catches twice as many trout as Mary. How many trout did Benny catch ?*

*Example 4: A restaurant sold 42 hamburgers last week. How many hamburgers on average were sold each day ?*

## II. RELATED WORK

Text categorization is a much explored area in machine learning. Sentiment analysis, different language identification, news group classification, information retrieval and summarization etc. are the areas where text classification has applied by using different algorithms. N-gram based approach is an earlier approach which showed classification on News between different languages. An extension had also been shown the subject similarity in the documents that are in the same language. Ikonomakis et al.,[7] has discussed various machine learning algorithms applied in text classification purpose. They have shown feature selection vectors and gave references to the open problems in this area.

An important field of classification and categorization of text have been explored by many researchers. Information retrieval, data mining, document similarity measures are the attractive areas of classification using machine learning and other hybrid techniques. This paper targets the mathematical word problem as a classification of text. So it is required to explore the other units of text which have already been classified using different methods. Jiang et. al.[1] proposed a document similarity measure using SMTP (Similarity Measure for Text Processing) feature selection. They have embedded presence and absence of features in similarity calculation. Search engine optimization needs an efficient text categorization algorithm. So web page classification is a requirement for all the search engines like Yahoo, Google, Bing etc. Ozel and Sarac[15] have selected Ant Colony Optimization for best feature selection to feed it on machine learning algorithms to get comparable result. Baharudin and Jaihadi [16] have tested a hybrid method consists of Ant Colony Optimization and Information Gain on text feature selection to categorize texts. They have successfully implemented these processes for dimensionality reductions of the features. Text categorization is not only bounded by documents, it also involves the texts which have Natural Language inputs. In this paper we have concentrated over word problems which show concise text with bounded categories. A number of works have been going on to automatically solve word problems as a natural text processing unit. Due to its diverse variety the word problems first need to be categorize in its specific type and then feed to solution process. Cetintas et al.[14] studied text categorization on two types of word

problems, Multiplicative compare and Equal group. They have used Support Vector Machine and combination of the variant of text processing. The comparison shows the effectiveness of stopword removal, stemming and utilization of part of speech tagging. In this paper a probabilistic weighted combination of SVM-NSTOP-NSTEM and SVM-NSTOP-NSTEM-POS used and concluded with a better result. This categorization has applied only on two types of word problems namely Multiplicative Compare and Equal Group. To solve word problems, classification will help to identify correct operators to choose between two numerals as suggested by Roy et al.[17] Arithmetic problems are expressed as a tree of numerals which can express the whole problem. They have also used multiclass classifier to predict the operation of two numbers.

## III. MACHINE LEARNING METHODS

In this paper we have used word problems to be categorized in addition, subtraction, multiplication and division problems. Bag-of-words are applied to linear classifier SVM, k-Nearest approach, Decision tree, Artificial Neural Network and Character level Convolutional Network from Deep learning .To apply machine learning methods noun phrases tagged as (NNPS and NNS), all verb phrases tagged as (VBD, VBG, VBP, VBZ), modal auxiliaries (MD), adverbs (WRB) are eliminated first. On the reduced text, keywords are selected as per their discrimination properties. Cetintas et al.[12] have eliminated all nouns tagged as NN, NNP, NNPS, NNS and adjective, numeral and ordinals(JJ) where as in our case some NN and JJ tagged words such as 'average', 'each' are used as they are highly discriminative. In their work they have classified only two cases Multiplicative Compare and Equal group with SVM and showed comparison between incorporation of stop-word removal and stemming. In this paper we have compared the machine learning methods along with deep learning classification.

Support Vector Machine has wide variety of application including Image classification, Text categorization, data mining, bioinformatics (protein classification, cancer classification), hand-written character recognition. To solve word problem, SVM is used for classification of problems and then solve them accordingly. Hosseini et al.[11] used SVM to

categorize verb to solve arithmetic problems which include only addition and subtraction. Here we have used multiclass classification in SVM which tests on four groups of problems. Decision tree algorithm is also an efficient machine learning algorithm. Heuristic search is also applied in Decision tree to optimize the search space. Neural Network and its variants are used in NLP, on a combination of multimodal applications on images and videos. Feed forward multilayer neural network is successfully applied on sentiment analysis and question answering. k-Nearest Neighbour and Neural Network algorithms are also tried to classify the same set of problems and compared the misclassification error on each algorithms. Recently deep learning has been applied in image processing, audio and video analysis. In Natural Language Processing also deep learning based algorithm shows remarkable performance in terms of speed and accuracy. The variants of deep learning such as CNN, Character level CNN, Recurrent CNN have already been applied on text classification. Here we have applied Convolutional Neural Network for classification of mathematical word problems.

In this variant of deep learning, words are concatenated and a window is specified for say k words.

So,  $X_{1:k} = X_1 + X_2 + X_3 + \dots + X_k$  Where + represent the concatenation. The features from each window is calculated as  $C_1$  for  $X_{1:k}$ ,  $C_2$  for  $X_{2:k+1}$  and so on, upto  $i$ th  $C_i$  by a non linear function  $f$ .

Where  $f = W.X + b$  and  $b$  is a bias

From the  $C$  vector the max pooling feature is selected.  $C = \max\{C_1, C_2, \dots, C_i\}$ . One feature is selected from one filter. Multiple features are selected from multiple window.

#### IV. RESULTS

As per literature review only a single paper has been found on categorization of mathematical word problems based on Multiplicative Compare and Equal Group problems. Other projects on mathematical word problem solving, have used sentence classifier but not the problem classifier. In our experiment we have collected word problems from MAWPS and made our own dataset from class 3 and 4 grade level as there is no such dataset available for our purpose. We have

compared the machine learning methods with deep learning Convolutional Neural Network.

Methods	Misclassification Error
SVM	0.2281
K-Nearest Neighbour	0.0702
Decision Tree	0.1049
Simple Neural Network	0.0050
Convolutional Neural Network	0.8

#### V. CONCLUSION

As the domain of categorization of word problem has not been explored much so we do not have standard databases for the required classification. The comparison on the collected data shows that the simple neural network is most efficient in this case. The text categorization on this domain can be explored on many other processes including evolutionary approaches and hybridization of machine learning methods with n-gram selection and as well as with different deep learning techniques.

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