Automatic Generation of Elementary Level Mathematical Questions

P. L. V. S. Keerthisrini

188100U

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
Master of Science in Computer Science and Engineering

Department of Computer Science & Engineering

University of Moratuwa
Sri Lanka

January 2020

DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date:

The above candidate has carried out research for the Masters thesis/Dissertation under my supervision.

Signature of the Supervisor: Date:

ACKNOWLEDGEMENTS

I am sincerely grateful for the advice and guidance of my supervisor Dr.Surangika Ranathunga. Without her help and encouragement this project would not have been completed. I would like to thank her for taking time out of her busy schedule to be available anytime that was needed with help and advice.

I would also like to thank my progress review committee, Professor. Sanath Jayasena and Dr. Amal Raj. Their valuable insights and guidance helped me immensely.

I would like to thank the entire staff of the Department of Computer Science and Engineering, both academic and non-academic for all their help during the course of this work and for providing me with the resources necessary to conduct my research.

The funding for this project was provided by the Senate Research grant, University of Moratuwa.

Finally, I wish to convey my sincere appreciation to Mr. Ruchira Jayathunga, Ms. Kulakshi Fernando, Ms. Ishadi Jayasinghe, Ms. Rameela Azeez, my family and all my friends for all the love and support.

Thank you!

ABSTRACT

Mathematical Word Problems (MWPs) play a vital role in mathematics education. An MWP is a combination of not only the numerical quantities, units, and variables, but also textual content. Therefore, in order to understand a particular MWP, a student requires knowledge in mathematics as well as in literacy. This makes it difficult to solve MWPs when compared with other types of mathematics problems. Therefore, students require a large number of similar questions to practice. On the other hand, the composition of numerical quantities, units, and mathematical operations impel the problems to possess specific constraints. Therefore, due to the inherent nature of MWPs, tutors find it difficult to produce a lot of similar yet creative questions. Therefore, there is a timely requirement of a platform that can automatically generate accurate and constraint-wise satisfied MWPs.

Due to the template-based nature of existing approaches for automatically generating MWPs, they tend to limit the creativity and novelty of the generated MWPs. Regarding the generation of MWPs in multiple languages, language-specific morphological and syntactic features paves way for extra constraints. Existing template-oriented techniques for MWP generation cannot identify constraints that are language-dependant, especially in morphologically rich yet low resource languages such as Sinhala and Tamil.

Utilizing deep neural language generation mechanisms, we deliver a solution for the aforementioned restrictions. This thesis elaborates an approach by which a Long Short Term Memory (LSTM) network which can generate simple MWPs while fulfilling above-mentioned constraints. The methodology inputs a blend of character embeddings, word embeddings, and Part of Speech (POS) tag embeddings to the LSTM network and the attention is produced for units and numerical values. We used our model to generate MWPS in three languages, English, Sinhala, and Tamil. Irrespective of the language, the model was capable of generating single and multi sentenced MWPs with an average BLEU score of more than 20%.

Keywords: Multi-lingual Mathematical Word Problem generation; Natural Language Generation; Neural Networks; Embeddings;

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

MWP	Mathematical Word Problem
RNN	Recurrent Neural Network
LSTM	Long Short Memory Network
CL-LSTM	Character Level Long Short Memory Network
WL-LSTM	Word Level Long Short Memory Network
RL	Reinforcement Learning
GAN	Generative Adversarial Network
MLE	Maximum Likelihood Estimation
OOV	Out-Of-Vocabulary