

# BSc AI Thesis - Project Plan

Title: Solving math word problems with controlled language

Author: Fabian Afatsawo - 12105155

Supervisor: Giovanni Sileno

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## Literature review

Since the invention of the calculator, computers do an excellent job in calculating math problems. The language used in math is a substrate of natural language (NL), using technical terms and grammatical conventions. Once given to a computer, it is converted to logic. One could say, the language of math is a subset of NL with a set of rules. In that sense, it is a controlled natural language (CNL). A CNL is a subset of NL that is human and machine-understandable. But, when math is expanded to NL computers have a hard time understanding it. A controlled natural language for mathematics (CLM) is developed [1] to solve this. This CLM is used as a step towards automatic formalisation and verification of textbook mathematical text. However, the coverage of CLM facilitates common reasoning patterns but is limited. The task of converting NL to First-Order Logic (FOL) remains an area of research. Direct approaches have been tried. Neural models showed difficulties in modelling NL to FOL [2]. The use of CNL could help form a bridge in this task. Research supports this approach wherein simplified English texts are converted from NL to Logic using CNL as an intermediate step [3]. Natural Language Processing (NLP) techniques make this conversion from NL to CNL possible. Further research supports this, wherein the conversion of legal text to CNL is attempted using NLP techniques [4]. To this day, simple middle school word math problems are difficult to solve for a computer. Attempts have been made by using autoregressive language models like GPT-3 [5]. A significant amount of research is focussing on converting NL straight into logic. Unfortunately, the results are still unsatisfiable. To tackle this, targeting primarily a conversion of NL to CNL might improve performance in this task [6]. Because CNL has a direct logical interpretation, it allows solving simple math problems given in textual form by using logic. Therefore, the core step of this method is the machine translation task from NL to CNL. The task requires a CL that is suited for making calculations. Attempto Controlled English (ACE) is a possible CL that is able to make this conversion [7]. It has a countable property and thus could be used to derive simple calculations.

# Research question

The task of solving simple math word problems using computers remains unsolved. The conversion from NL to CNL seems a promising approach to tackle this task. This is because CNL has a direct logical interpretation, at which calculations could be done. Hence, can simple math word problems be solved by utilizing a CNL?

# Method and approach

A proof of concept will be pursued. Hereby, the focus is on a conversion from NL to CNL and from ACE compliant text to calculation.

First, NLP techniques will be used to convert NL to CNL. The syntax of NL will be extracted with parse trees and POS tags. This extracted syntax will be transformed into an ACE compliant syntax. With this, a transformation made of syntax and NL to an ACE compliant text.

Secondly, the ACE Parsing Engine (APE) will be used to derive the logical interpretation of ACE compliant sentences. APE is able to parse ACE compliant sentences and is publicly available. A calculator will be made to derive calculations from these logical interpretations.

The data (word problems) that will be used are sourced and generated.

Once the proof of concept is made, ....

# Evaluation

APE will be used as a validator for CL. In this way, text converted from NL to CL will be evaluated. The respective answers to the word problems are fixed and known. Thus, these answers will be used to evaluate the calculated answers.

# Plan

Gantt-chart at end of the file.

# Report and presentations

The report will be written throughout the project. Towards the end of the project, more time will be assigned to this task. For this 2/3 weeks are in mind at the moment. Time is also set aside for preparing presentations, this will be one week. The choice on how to carry out the presentation is open. This can be either physical or through a pre-recorded video.

# Bibliography

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- [4] Dragoni, M., Villata, S., Rizzi, W., & Governatori, G. (2016). Combining NLP Approaches for Rule Extraction from Legal Documents. In *Proceedings of the workshop on "Mining and Reasoning with Legal Texts" collocated at the 29th International Conference on Legal Knowledge and Information Systems*.
- [5] Cobbe, K., Kosaraju, V., Bavarian, M., Hilton, J., Nakano, R., Hesse, C., & Schulman, J. (2021). Training Verifiers to Solve Math Word Problems. *arXiv preprint arXiv:2110.14168*.
- [6] Hales, T. (2019). An Argument for Controlled Natural Languages in Mathematics.
- [7] Fuchs, N. E., & Schwitter, R. (1996). Attempto controlled english (ace). *arXiv preprint cmp-lg/9603003*.

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Plan

Fabian Afatsawo

Project Start:11/12/2021

Display Week:1

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