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Arabic Arithmetic Word Problems Solver

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Abstract

The recent evolution in Natural Language Processing (NLP) and machine learning have played a crucial role in the development of solving word problems written in human language. This paper, to the best of our knowledge, presents the first attempt of automatically solving Arabic arithmetic word problems. In addition, as part of this work, we prepared an Arabic annotated dataset by translating a standard arithmetic word problems English dataset (AddSub Dataset). The AddSub dataset has been used by several researchers to evaluate their models for English arithmetic word problems. The proposed algorithm relies on our automatic verbs learning approach based on the training dataset. Moreover, the algorithm utilizes various NLP tools to assign objects to problem states until reaching to the goal state such as Stanford Parser, Named Entity Recognition (NER), and Cosine Metric Distance. Our approach overcomes various issues such as tracking both entities and their related results during the transfer process as well as dealing with different forms of the same verb. The performance evaluation process showed promising results resolving 80.78% of the problems. On the other hand, there are still several areas that can be extended and improved. For instance, the lack of common knowledge, presence of irrelevant information, and quantity conversions.

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1. Introduction

Arithmetic word problems are one of the interesting topics in Artificial Intelligence (AI) and Knowledge Representation and Reasoning (KRR). In the last few years, various attempts took place to develop and train machines to automatically solve and understand arithmetic word problems. The massive growth in NLP and the technology in general have great influence in interpreting natural language to be understandable by machines as well as overcoming various issues in reasoning tasks. Hence, NLP is considered as an essential party in AI and KRR development, particularly in answering arithmetic word problems written in human language.

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Briefly, arithmetic word problems include some kind of logic or formula and essentially entail arithmetic equation to solve it [9]. On the other hand, Koncel-Kedziorski et al. [6] articulated that arithmetic word problems is a typical problem that initially defines a part of world state including characters, entities and quantities. Then it alters the state of an entity or clarifies the connection between entities. At the end, it points to a question about a quantity in the story.

Arithmetic word problems that deal with addition and subtraction operations, can be categorized under three classifications: join and separate (J-S), part-part-whole (p-p-w) and compare [1]. Furthermore, each word problem entails a set of sentences, each sentence reflects a modification in the problem state. For instance, (J-S) problem usually contains three main modification sentences: the quantity given in the initial state, the change sentence where a quantity is transferred from an entity to another, and the result sentence which aims to find the result of the modification applied to the given quantity. On the other hand, compare is considered as the simplest problem category. It embraces a comparison between two sets of quantities. Finally, (p-p-w) problem has two types of functional sentences: part which specifies the quantity of a set, and whole which specifies the total amount of group of sets. Table 1 recaps the mentioned categories as well as an example for each.

Table 1. Examples for different categories of arithmetic word problems.

Category	Example	Equation
Join and Separate	وجد عمر ٣٥ صدفة على الشاطئ. أعطى عمر لجاسم ١٨ صدفة. كم عدد الصدف التي لدى عمر الآن ؟ Omar found 35 seashells on the beach. Omar gave Jasim 18 seashells. How many seashells Omar has now?	Given: 35 Transferred: 18 Result: X X = 35 - 18
Part-Part-Whole	يوجد مع سهى ٢٢ كتابا. يوجد مع ناصر ٢٠ كتابا. كم عدد الكتب التي لديهما معا ؟ Suha has 22 books. Nasser has 20 books. How many books do they have together?	Part: 20, 22 Whole: X X = 20 + 22
Compare	مع عمر ٨٠ درهم. ومع أسامة ٥٠ درهم. كم درهم يملك عمر أكثر من أسامة ؟ Omar has 80 dirhams. And with Osama 50 dirhams. How many more dirhams Omar has than Osama?	Greater Value: 80 Smaller Value: 50 X = 80 - 50

This paper, to the best of our knowledge, presents the first attempt of automatic resolution of Arabic arithmetic word problems. In addition, as part of this work and due to the unavailability of annotated dataset, we started by translating one of the standard publicly available arithmetic word problems AddSub[1] dataset from English to Arabic to address the gap between the two worlds. This dataset were used by several researchers to evaluate their models for English arithmetic word problem, such as Hosseini et al. [5], Roy and Roth [10], and Mitra and Baral [8]. Our objective is to produce a system capable of understanding and solving Arabic arithmetic word problems. The system is built using Java programming language and has utilized NLP tools and libraries that support Arabic language. For instance, the Stanford Parser[2] to parse the word problems text and extract the verbs [4], in addition to a set of 8900 tagged Arabic words for NER[3] [3][2].

In the next "Related Work" section, we present the significant similar researches that have been done recently for English arithmetic word problems. After that, the representation of the problem states and how the algorithm moves between them until reaching the goal state is illustrated in "Problem Representation" section. In addition, section "Building Dataset" describes the characteristics of the produced dataset and "Algorithm Description" section provides a step-by-step details of the proposed model and the tasks initiated to solve the word problems. Then, the "Experimental Evaluation" section illustrates the evaluation process and the performance results. In addition, the main challenges and errors are discussed and analysed. Finally, the "Conclusion and Future Word" section highlights the

[1] https://www.cs.washington.edu/nlp/arithmetic
[2] https://nlp.stanford.edu/software/lex-parser.shtml
[3] http://www1.ccls.columbia.edu/ ybenajiba/downloads.html

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