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Indonesian Question Answering System for Solving Arithmetic Word Problems on Intelligent Humanoid Robot

Alexander A S Gunawan [a]*, Pribadi R Mulyono [b], Widodo Budiharto [b]

[a] *Mathematics Department, School of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480*
[b] *Computer Science Department, School of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480*

Abstract

This paper presents our research on Indonesian question answering system for solving arithmetic word problems using pattern matching approach on intelligent humanoid robot. The objective of this paper is to elaborate how natural language processing (NLP) and pattern matching approach works in question answering system for solving arithmetic word problems. Upon receiving a Indonesian arithmetic word problem, the robot will translate Indonesian speech to English text, resolve conjunction problem, co-references problem, question preprocessing, question analysis, represent the knowledge, and lastly the robot will answer the solution. We employed NLP for English by using Natural Language Toolkit (NLTK) in our research. Based on the experiment results, it can be concluded that: (i) the accuracy of the question answering system for each scheme ranges from 80% to 100% depend on the difficulty to comprehend the word problem, (ii) the response time is rather slow with average processing time is about 1.12 minutes.

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1. Introduction

Robots are becoming useful parts in the education where robots can be used for the student development and

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: aagung@binus.edu

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intellectual growth [1]. Humanoid robots, with their humanlike appearance, enhance another dimension for interaction between robots and human by various capabilities, such as the ability to perceive people and recognize human language. The development of humanoid robots in education for teaching and learning has become a widespread and challenging research topic. Consequently, greater attention must be put onto how educational robots can be better integrated into school curriculum. With the advent of robotic technology, it is valuable to tap the potential of robots as effective learning parts, mainly for STEM (science, technology, engineering, and mathematics). Nowadays, educational robotics is viewed as a transformational tool for STEM learning [2]. Teaching and learning in mathematics, which is crucial ingredient of STEM, need to change from the traditional methods to the modern methods that integrated the recent technologies as in China [3].

Our vision in this research is to implement the first grand challenge in education, that is to create mentors for every students [4]. The challenge emphasizes on applying artificial intelligence (AI) that can act as mentors and interact with students in natural ways. Therefore, we want all students to have their own personal robot, which is embedded with AI, that can interacts and teaches students the main lesson such as arithmetics. In this paper, we would like to present our research in developing intelligent humanoid robot for learning arithmetic. Our humanoid robot is designed to solve arithmetic word problems involving subtraction or addition operation given in Bahasa Indonesia. We used our previous humanoid robot [5], RAPIRO, for this arithmetic word problem research. RAPIRO is a small and affordable robot designed to work with a Raspberry Pi. It works with Arduino-compatible microcontroller as servo controller. RAPIRO has a torso, a head, two arms, and two legs, though it only uses 12 servo motors.

To implement our objective, we used one application of AI, that is question answering (QA) system. QA attempts to search the correct answer to the question pose in natural language [6]. In general, the system has three components, that is: question classification, information retrieval, and answer extraction. The common data source for QA system is mainly in text form, thus our first challenge is to convert speech to text. In this research, we focused the QA system to solve aritmetic word problems (AWP) [7]. The aim is to solve aritmetic problems involving addition and subtraction which is given in Indonesian. It uses the principles of natural language processing (NLP) to extract information from the question and to construct the correct answer. For NLP, arithmetic word problems are primarily attractive because the problem is concise and straightforward, while the semantics can be extracted to simple equations. The main different of our research to literature in AWS is the input which is the user speech to our humanoid robot. The speech must be converted into text and then it is processed by applying many principles of NLP to get the correct answer. Finally, the answer has to be converted back in form of robot's speech.

The remainder of this paper is composed as follows: first we discuss the arithmetic word problem (AWP) and how to solve it in section 2, and then is followed by implementation in our humanoid robot in section 3. In section 4, we report the experiment result in accuracy of QA system. Finally, we review our work with suggestions to our future research in section 5.

2. Arithmetic Word Problem

Arithmetic word problems (AWP) constitute an integral part of elementary schooling curriculum [8]. Solving an AWP is a complex task involving critical aspects of reading comprehension, understanding the problem and generating a solution that answers the word problem. Commonly students are taught the problem solving skill by the use of various strategies. In our research, we view AWP as a question-answering problem, involving question classification, information retrieval, and answer extraction and solve by applying several NLP principles. It is an ideal starting point for developing full question answering system because AWP is relatively easy to measure performance. We can unambiguously determine that the solutions of a math problem is correct or not. Furthermore, math word problems typically contain brief text with clear semantics.

The first effort to solve arithmetic word problem was by Bobrow [9] as part of his PhD dissertation in 1964. His proposed method could solve an algebra problem in a subset of natural language by extracting information from the ambiguous sentences. In 1986, Dellarosa [10] used schemas to solve addition and subtraction problems for classifying entities. Schemas can be considered as templates for problem solving. Next in 2007, Bakman [11] proposed a method to improve the schemas by extending them to handle extraneous information and his approach can solve multi-step problems unlike the previous schemas. Liguda & Pfeiffer [12] proposed modeling math word problems with augmented semantic networks in 2012. It used a natural-language processing pipeline that augments the input text

with annotations. The approach does not rely on specific patterns and does not depend on the semantic structure of the text for text understanding. We can call the above works as symbolic approaches, where math problem sentences are transformed to specific structures by using pattern matching. The math equation is then derived from the structures. In this research, we used the pattern matching approach, but the math problems are in Bahasa Indonesia.

The second approach is statistical learning methods. The main idea of statistical learning methods is to map natural language to formal meaning representation by using learning algorithm. Hosseini et al [13] solve homogenous addition and subtraction problems by learning to predict verb categories in sentences. Kushman et al [14] can solve various word problems by constructing systems of equations and aligning the variables and numbers from the word problem. The recent paper from Amnueypornsakul [15] used text classification approach to solving AWP. It employed random forest for classifier and showed it give the best results for identifying the problem type and the discourse structure. These learning approach, of course, needs a large text corpus as training data.

As said above, our work used the pattern matching approach inspired by Sundaram paper [7]. The arithmetic word problems are represented in Bahasa Indonesia involving subtraction or addition operation. Here is an example of our input and output of the math problem.

Input: Eric mempunyai 5 butir telur. Kemudian eric kehilangan 1 butir telur. Berapakah telur eric sekarang ?
(Eric has 5 eggs. Then he loses 1 egg. How many eggs does Eric have now?)

Output : Eric memiliki 4 telur.
(Eric has 4 eggs)

As we know, natural language processing in Bahasa Indonesia is not mature yet. There is only restricted tools for analyzing text in Bahasa such as InaNLP [16]. It contains several NLP modules such as sentence splitter, tokenization, and Part of Speech (POS) tagger, but there is no NLP tool for the reference resolution and a dependency parser. On the other hand, there is complete and mature toolkit for symbolic and statistical natural language processing (NLP) for English, that is Natural Language Toolkit (NLTK) [17]. It was developed by Steven Bird and Edward Loper from University of Pennsylvania. Therefore, we would like to exploit the NLTK for our initial research in question answering problem. Furthermore, our approach is first to translate the word problem in Bahasa into English and then processed by using NLTK. We used google translate API for language translation. We will deal to Indonesian NLP directly in next research. In Fig 1, we describe workflow of our approach to design Indonesian question answering system for solving arithmetic word problems, which employs a natural-language processing pipeline. We will discuss in detail this workflow in next section.

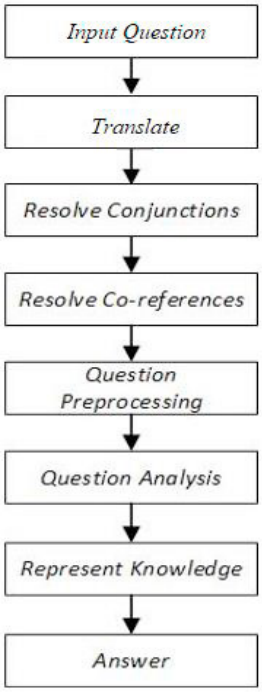


Fig. 1. Workflow of question answering system

3. Implementation in Intelligent Humanoid Robot

Our purpose of the research is to solve the problem of arithmetic word problems in the subtraction or addition operation given in Bahasa Indonesia by using various NLP principles. The user interface is our humanoid robot [5], consequently the input is the user speech to the robot. The question answering system is developed by using Python programming language on our intelligent humanoid robot RAPIRO which based on Raspberry Pi. In order to use various techniques in NLP such as tokenizer and POS tagging, the user speech first is converted into text. The main processes to get the final answer is to determine the keywords and the arithmetic operator from the word problem. The question answering system also needs to identify personal pronouns and entity relationship in the sentences. To solve this problem, the word math problem must be divided into each sentences and words, and the determine its pattern by using schema. The complete workflow of our approach can be seen in Fig.1. We will discuss each step of the workflow below.

3.1. Input Question

At this step, the user asks questions about arithmetic word problems in Bahasa Indonesia to our humanoid robot. The robot then processes the speech into text. The conversion of Indonesian speech to text is by using microphone and Google Cloud Speech-to-Text [18]. To use Google Cloud service, our humanoid robot must be connected to the internet.

3.2. Translate

In this stage, the robot translates the Indonesian word problem given by the user into a sentence in English. For the translation process from Indonesian text to English text, we use the Google Translate API and Googletrans library [19].

3.3. Resolve Conjunctions

At this stage, the question will be simplified when it contains conjunctions and certain keywords, such as *and, but, for, nor, or* etc. Suppose the recorded word problem is: “Budi has 2 apples and 3 oranges then he buys 1 apple how many apples does Budi have”. The conjunction resolving for this word problem in here are:

1. Sentences are splitted into two parts based on the conjunction. If the entity in the second part is empty, then the empty part will be filled with the entity from the first part. For example: “Budi has 2 apples and 3 oranges" is a conjunctional sentence and it will be splitted into "Budi has 2 apples" and " Budi has 3 oranges".
2. If the part does not contain a verb then there is no process required. And if the part contains a verb, then divide it into three fragments ie pre-verb (P), verb (V) and after-verb (A), for example: "Budi (P) has (V) 2 apples (A)"

The remain sentence in the example: “then he buys 1 apple how many apples does Budi have" will be splitted based on keywords. In this case “*how* to” is the keyword to split the question, then the result is "then he buys 1 apple" and "how many apples does Budi have". The end result of above example is four parts of sentences: (i) “Budi has 2 apples”, (ii) “Budi has 3 oranges”, (iii) “then he buys 1 apple”, (iv) “how many apples does Budi have".

3.4. Resolve Co-references

Co-references occur when two or many expressions in a sentence refer to the same thing or to the same person. Each part in previous step will check whether it contains a pronoun such as he, she, it etc. If it is found a pronoun, then it will be replaced with the reference. For example, we found the third part has a pronoun: “then he buys 1 apple". In here, “he” is referred to “Budi”, then the part is corrected to be "then Budi buys 1 apple".

3.5. Question Preprocessing

Before analyzing the question, we performed preprocessing to simplify the problem in classification. There are two preprocessing steps, that is (i) tokenizing and (ii) stop word removal. Tokenizing is the task of chopping the sentences into words. For example, the previous result: “Budi has 2 apples” is broken down by tokenizing process into “Budi”, “has”, “2”, “apples”. The next preprocessing is stop word removal. Stop word removal is a process of eliminating a useless or trivial word, such as the word "then". Thus, the previous result: “then Budi buys 1 apple” is filtered into “Budi”, “buys”, “1”, “apple”.

3.6. Question Analysis

At this stage, we search information based on data resulted in the preprocessing step. To identify the key phrases in the text, the system employed (i) named entity recognition (NER) and (ii) part of speech *tagging* (POS Tagging). The example of NER in the part: "Budi has 3 oranges", “Budi” is a person entity. Next the example of POS Tagging results for: "Budi has 3 oranges" is Budi / NNP has / VBT 3 / CDP oranges / NN.

3.7. Represent Knowledge

After getting the relevant key phrases in the text, then it is matched to the predefined pattern schema in Table 1. Seen the appropriate pattern then form a mathematical equation. The scheme formed is as follows:

Table 1. List of predefined pattern schema

Schema	Word	Sentence	Equation
Having	(have)	Budi has 2 apples	Budi = 2
Change out	(give to)	Budi give 3 apples to Andi	Budi = x – 3 Andi = y + 3
Change in	(asked from, given by)	Budi asked for 2 apples from Anto	Budi = x + 2 Anto = y – 2
Increase	(find, buy)	Budi find 2 Apples	Budi = x + 2
Reduction	(eat, broken, lost)	Budi ate 2 apples	Budi = x – 2
Compare plus	(more than)	Budi has 2 more apples than Anto	Budi = Anto + 2 Anto = x
Compare minus	(fewer than)	Budi has 2 fewer apples than Anto	Budi = Anto - 2 Anto = x
Combine	(all, whole)	Budi has 2 apples. Anto has 3 apples. How many apples are there?	Budi = 2 Anto = 3 ALL = Budi + Anto

3.8. Answer

From the obtained mathematical equation, we can calculate the answer of arithmetic word problem. The solution is then re-translated into Bahasa by using Google Translate API and synthesize into voice by using gTTS (Google Text To Speech) library [20].

The question answering system for solving arithmetic word problem have been developed succesfully on our intelligent humanoid robot RAPIRO. Here is the usage step system of question answering system on humanoid robot:

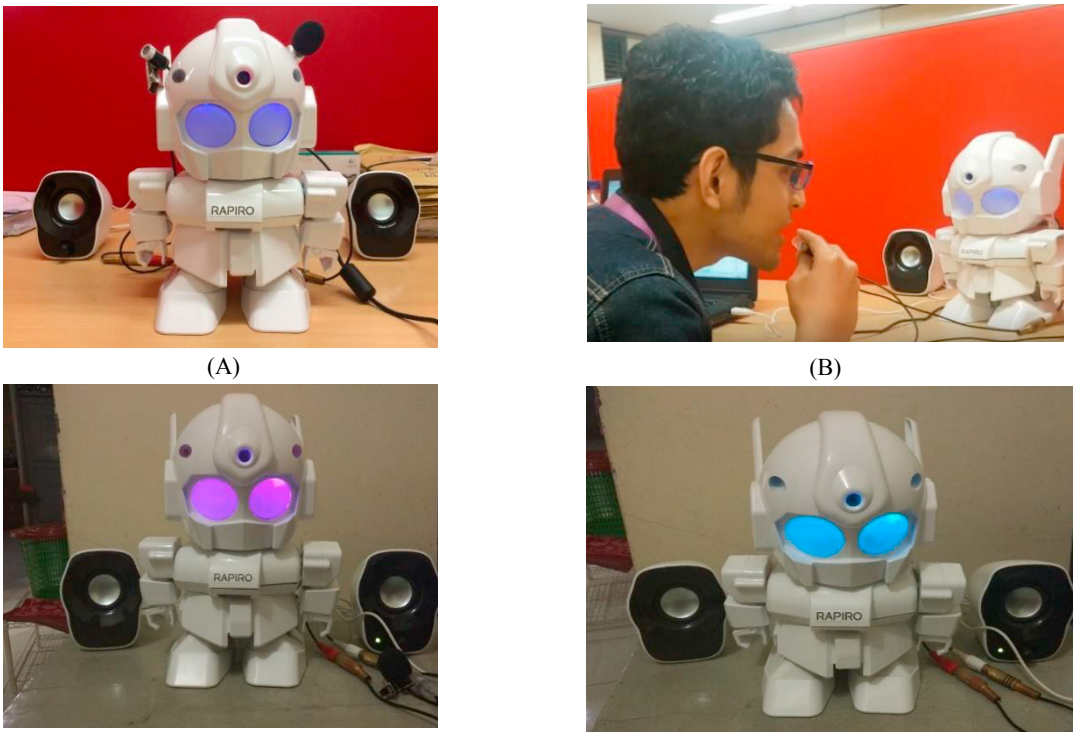
A. When starting the question answering system, the blue LED light on the robot eyes indicate the system is ready.

The robot will say hello and give a signal for user to ask any arithmetic word problem.

B. The user is required to ask and the robot will listen the user speech. The user is given the duration up to 10 second to ask word problem.

C. After the user asks the question, the robot requires a few minutes to process the question. Meanwhile, the robot will say "tunggu sebentar (please wait a minute)" to signify that the system needs some processing time. The LED light on the robot eye will be red indicating the robot is processing.

D. After processing the question by using question answering system (see Fig. 1), the robot will calculate the result and tells the solution in Bahasa. The LED light on the robot eye will be light blue indicating the robot gives response to the question. Furthermore, the robot will ask user whether they want to ask more question or not by saying "Apakah anda ingin bertanya lagi? (Do you want to ask again?)". If the user says "ya (yes)", the process will go back to step A. Otherwise, the robot will say "terima kasih (thank you)" and terminate the system.



(A) (B)

(C) (D)

Fig. 2. (A) robot in ready state, (2) user ask question, (3) question processing, and (4) robot answer the solution

4. Experiment Results

In the experiment, we measure the speed of the system in providing answers and measure the accuracy of answers generated by our question answering system. There are seven participants who evaluate the question answering system. There are 42 questions for all types of schema in Table 1 to test the speed and accuracy of the system. Therefore, each participant will ask six questions to our robot. From the experiment, it was found that the answers that is generated from the 42 questions, had an average processing time of 1.21 minutes. Furthermore, the experiment result of system accuracy can be seen in Table 2 below. Important to note that every math word problem has "Having" schema. The calculation of average in Table 2 is without considering "Having" schema.

Table 2. Experiment results

Schema	Number of questions	Number of correct answers	Accuracy
Combine	8	8	100%
Increase	9	9	100%
Reduction	5	5	100%
Change Out	5	4	80%
Change In	5	5	100%
Compare Plus	5	5	100%
Compare Minus	5	4	80%
Having	42	42	100%
Average			94%

5. Conclusion

In this paper, we have successfully implemented Indonesian question answering system for solving arithmetic word problem in our humanoid robot by using pattern matching approach. Based on the experiment results, it can be concluded that: (i) the accuracy of the question answering system for each scheme ranges from 80% to 100% depend on the difficulty to comprehend the word problem. This impressive result is due to the reliability of NLP toolkit for English in NLTK library. (ii) the response time is rather slow with average processing time is about 1.12 minutes. It is mainly because the robot needs to connect the internet directly in the process of converting speech to text. Furthermore, the accuracy of speech recognition and language translation into proper English text is critical to get the correct answer. We observed that some mistakes are caused by inaccuracies in language translation. It can make difficult to extract knowledge and get the right pattern.

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