Sri Lanka Institute of Information Technology

Arithmetic Problem Solving System for Grade 5 Students using neural networks

(මහෞෂධ2)

Project Proposal Report - CDAP-I

Bachelor of Science (Special Honors) in Information Technology

Title :	Mathematical Problem solving system for grade 5 students (mahoshada 2)
Project ID :	
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Declaration

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Abstract

We present an approach for automatically learning to solve arithmetic word problems. Our algorithm reasons across sentence boundaries to construct and solve a system of linear equations, while simultaneously recovering an alignment of the variables and numbers in these equations to the problem text. In this project we are going to apply some of the Natural Language Processing (NLP) techniques to analyze the Sinhala language to gain a better understanding of the language in an NLP perspective and as a step towards developing more complex tools for solving mathematical problems. In our research we suppose to build a simple neural network. In the conventional approach to programming, we tell the computer what to do, breaking big problems up into many small, precisely defined tasks that the computer can easily perform. By contrast, in a neural network we don't tell the computer how to solve our problem. Instead, it learns from observational data, figuring out its own solution to the problem at hand. We used this technology for our research to improve the quality of our project. This will be used to simulate the development of children's ability to solve equivalence problems. The model treats algebraic problem solving as an acquired skill, emerging slowly from practice solving example problems. The expected system is more profitable since it deals with the main issues of the students who have the lack of knowledge about algebra word problems.

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1. Introduction

1.1 Background

People always wanted computers to act intelligent. To accomplish this task the field of Artificial Intelligence came into existence. One of the key barriers in making computers intelligent is understanding of Natural Language. Natural language processing which deals with understanding of languages is sub division of Artificial Intelligence. Question Answering is a classic NLP application. It has practical applications in various domains. Most of the available system's Task that a question answering system realizes is given a question and collection of documents, finds the exact answer for the question.
In this project we are going to apply some of the Natural Language Processing (NLP) techniques to analyze the Sinhala language to gain a better understanding of the language in an NLP perspective and as a step towards developing more complex tools for algebra word problem solving in Sinhala.

Designing algorithms to solve math problems is a challenge. Arithmetic world problems describing world state and pose question about it so that state can be modeled using equations whose question's answers. For a child language understanding part is little bit tough when we give arithmetic word problem they should identify what are the category they must consider and solve the problem. Arithmetic word problems are an important practical application of mathematics since real world problems usually do not arise in terms of equations but as verbal or pictorial representations.

In our literature survey we found out that the most relevant and best researches at IBM built unstructured information management architecture, a frame work to integrate various computer software each different and independent to work together .It was a real time and scalable question answering system.IBM Watson does not cover up solving mathematical problems. But the project that is to be developed is based on

mathematical sentence problem solving. In comparison to IBM Watson main difference is that “Mahoshada 2“is developed for Sinhala language.

Although there are many advanced related systems for English language, there is no any system for Sinhala language. This research will be a great opportunity to Sinhalese who are expecting this type of system in their native language. This document will further describe our objectives of doing this type of research and how we expect to do the research and many other related details. This is an encouraging start for further research on the Sinhala language.

1.2 Literature Review

There are prominent research based on Question Answering on IQ questions [1, 2, 3]. It was found that the task of a question answering system is finding the exact answer for a given question by finding out through relevant documentation on internet. Most of these systems are not working on solving mathematical sentence problems. None is developed in Sinhala language yet.

There’s a simple pipeline architecture for natural language is presented [2]. In the system a problem is analyzed with a combinatory categorical grammar coupled with a semantic representation theory to derive a logical form .As well as they used math algorithm and theorem to prove. But the whole process of problem solving is done by using English language .So in our system we mainly focus to do it in Sinhala language.

Proposed system When identifying mathematical operation defined in the problem firstly we need to generate a meaning with the key words .In order to do that [3] we calculate PMI values for each key word and find the word similarity, Word similarity is a measure of how semantically similar a pair of words are, with synonyms having the highest value. It is widely used for applications in natural language processing (NLP), information retrieval, and artificial intelligence.
Most of the existing systems do wordNet based similarity measures that typically depend heavily on IS-A information, which are available for nouns but incomplete for

verbs and completely lacking for adjectives and adverbs. Mathematical problem are normally attractive because the text is relatively straightforward. According to the paper, the system identifies the relevant variables and the values by analyzing each of the sentences in the problem. Then it maps the information into an equation that represents the problem, and after that generates the answer.

The system 'ARIS' is based on variable / value analyzing, key word extraction etc.
ARIS only relies on learning verb categories which alleviates the need for equation templates for arithmetic problems In English language. But proposed system distinguishes from this system by using all above methods in Sinhala language.

There's an approach for automatically learning to solve algebra word problems. Using algorithm constructs a systems of equations while aligning their variables and numbers to problem text .whole solution specifies the questions' answers [5].When they define a two-step process to map word problems to equations. First, a template is selected to define the overall structure of the equation system. Next, the template is instantiated with numbers and nouns from the text. During inference they consider these two steps jointly.
Their focus is on learning a model for the end-to-end task of solving word problems given only a training corpus of questions paired with equations or answers.

This is introduced as kind of a lexical resource for natural language processing and linguistic tasks such as word sense disambiguation. Under this research word selection, sense identification, sense relational extraction, translation (from Sinhala to English), identifying the appropriate senses take place.[6] Simply, they translate the Sinhala word into English and insert the word into an existing WordNet sense identifier. Even though this is not based on question answering, this research which is done in Sinhala language well explains how the usage of WordNet is done. Most of the question answering approaches use WordNet in checking word similarity.

Morphological parser capable of analyzing and generating Sinhala verbs .Sinhala language is a morphologically rich language. [7] Which gives rise to 110 word forms for nouns and 282 word forms for verbs. Verbs are being categorized into many forms within Sinhala language. Also there are 4 basic groups of verb roots too.
Morphology is an important area in computational linguistic. It explains word structure, formation of words and how the words are related to other words.
Under morphological parsing a computation is done.

1.3Research Gap

Although there are many advanced related systems for question answering systems in English language most of them are available for information retrieval only, simply they access the document and get the answers for the questions. In this proposed system our main target to solve mathematical problems in Sinhala language. It is not a kind of information retrieving .identifying the mathematical question is a difficult task we supposed to archive this goal and every job is done through the neural network.

1.4 Research problem

Question Answering is a specialized form of Information Retrieval which seeks knowledge. Proposed mathematical problem solving system that is capable of understanding a detailed sentence mathematical problem in Sinhala language. Main research problem is have to come up with a solution to understand the Sinhala language of the system and to analyze it and come up with an algorithm to build questions in the correct Sinhala grammar format and the other thing is providing the question to the user will be done by displaying it on the screen.

To make this possible, we should make the system to read the Sinhala language and also to understand the answer given by the user .we are planning to summarize Sinhala context that is given to the system.

The focus of this action research is mathematics problem solving in Sinhala so we have to identify which problem solving methods students choose to solve a problem. The purpose of this study is to determine if students solve math problems using addition, subtraction, multiplication, and division consistently and whether students transfer these skills to other mathematical situations and solutions. In this action research study, a classroom of 5th grade mathematics students was used to investigate how students solve word problems and how they determine which mathematical approach to use to solve a problem. It was discovered that many of the students read and re-read a question before they try to find an answer.

Most students will check their answer to determine if it is correct and makes sense. Most students agree that mastering basic math facts is very important for problem solving and prefer mathematics that does not focus on problem solving. As a result of this research, it will be emphasized to the building principal and staff the need for a unified and focused curriculum with a scope and sequence for delivery that is consistently followed.

2. Objectives

2.1 Main Objective

Develop a system that is capable of solving grade 5 mathematical word problems. for that system must be able to take an arithmetic mathematical word problem as a text, understand the question and solve the problem. Answer should be presented to the student as a simulation so that the child can understand it more easily

2.2 Specific objectives

2.2.1 Maintain better interaction with user and the system.

2.2.1.1 Provide an attractive user interface that suits for students in age of 9 – 10.

Interfaces should be attractive with eye catching colors and suitable features that students in the age range of 9-10 can be attracted easily.

2.2.1.2 Providing a user friendly interface for users.

Interfaces should be very user friendly so that students can easily get their work done through the system without wasting time on struggling how to operate the system.

2.2.2 Cover up all the areas in the scholarship syllabus that deal with addition and subtraction operations.

System covers up

- Addition in number theory
- Subtraction in number theory
- Calculating area.
- Currency
- Fractions
- Time calculations
- Decimal calculations
- Weight, length, volume and capacity calculations

2.2.3 Understand correctly the given mathematical problem by the system.

System should be capable of correctly understanding the mathematical problem given as the input

To understand the mathematical problem system should extract the verbs and entities correctly.

2.2.3.1 Perform keyword identification

First of all system must split the mathematical problem into smaller entities. Out of those entities most relevant words are extracted as key words.

2.2.3.2 Perform verb categorization

Determining the meaning of the question is done with the verbs and entities. Correct identification of verbs and entities must be done.

2.2.3.3 Identify correctly the relevant mathematical operation for a given problem

System is required to be capable of understanding whether an addition or subtraction should be performed.

2.2.4 Make the final output more understandable for the user

2.2.4.1 Create correct and comprehensive simulations for each problem.

System must provide the student not only the final answer, but also the way that the problem was solves. The simulations must be easy to understand and attractive.

2.2.5 Increase the accuracy of the system

2.2.6 Create a neural network to achieve the accuracy

Neural network will check the accuracy and choose the most suitable outcomes of the key word identification and mathematical operation identification.

3. Methodology

"Arithmetic word problem solving using neural network" is implemented to provide grade 5 scholarship students to learn how to solve mathematical problems. Under this topic it is described the development process, the methods and techniques that will be used to develop this system.

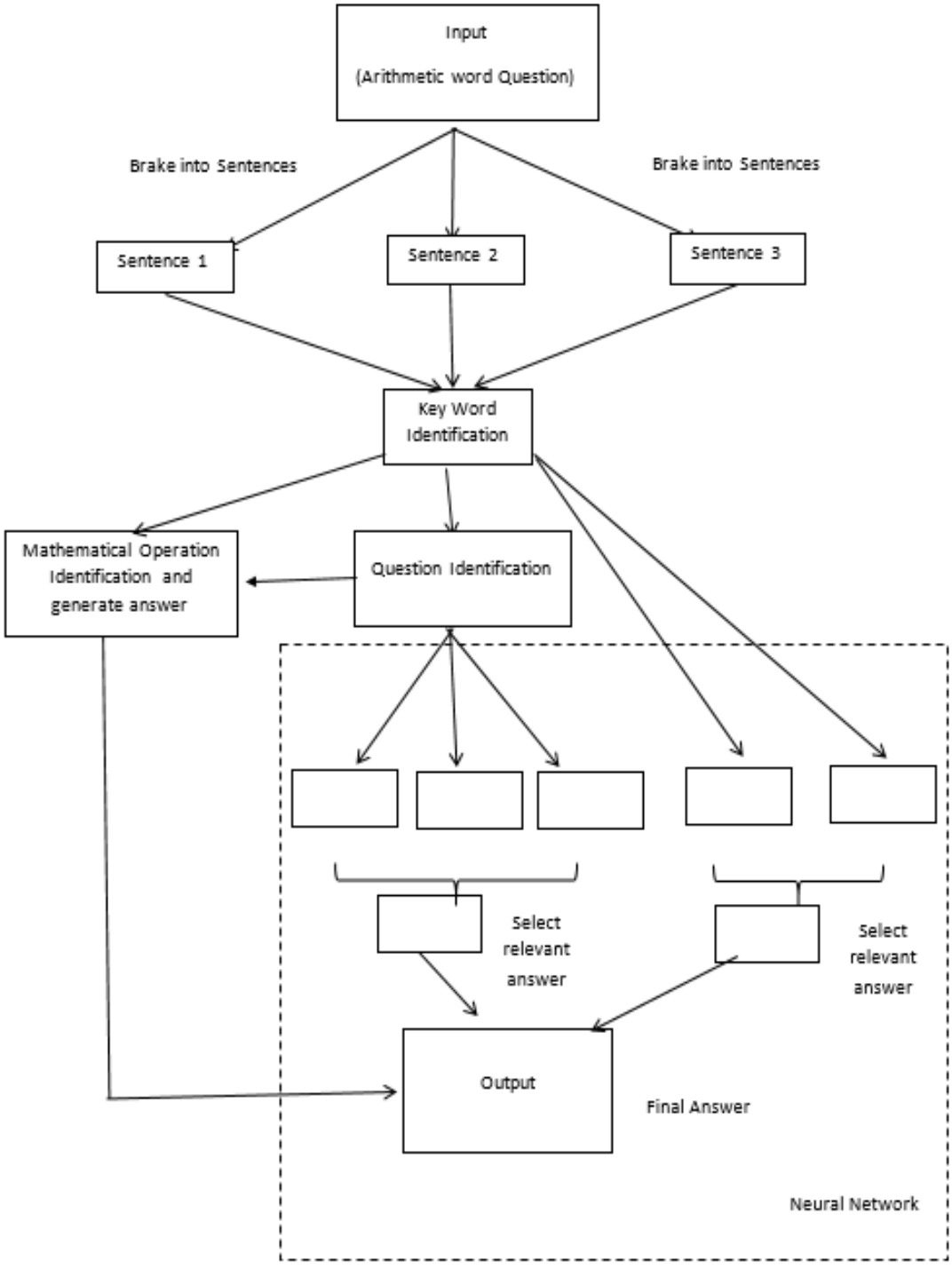


Figure 1 Architecture of proposed system

According to the above diagram, once the mathematical problem is inserted to the system, system breaks down the problem in to sentences. Key word identification is done for each sentence. Question identification is done in parallel to the key word identification. Identifying the required mathematical operation and performing it is done as the next step. Then the neural network will output the correct answer. Finally the answer will be displayed with simulations to the child. It is important to show the child that how the problem is solved in an attractive manner that will encourage the child to attempt in to this subject even more.

3.1 Key word identification

Key word identification

Extracting key words is a most important thing when working with text form of Arithmetic question. Because by identifying key words can judge very quickly the text is worth reading and Keywords in a question provide the most important information about the content of the question.

Candidate selection:

First, we need to identify verbs and nouns In a Sinhala content before identify the keywords. Sinhala language is a complex language so in a sentence there may be more than one noun and one verb. So the first step is to identify those things. To do that we need to use a parser.

Parse trees can be used to represent real-world constructions like sentences or mathematical expressions. Figure 2 shows the hierarchical structure of a simple sentence. Representing a sentence as a tree structure allows us to work with the individual parts of the sentence by using sub trees.

Eg : මා ලග අඹ ගෙඩි 10 ක් ඇත. ඉන් 2 ක් මල්ලීට දුන්නේය. මා ලග ඉතුරු අඹ ගෙඩි කොපමණද ?

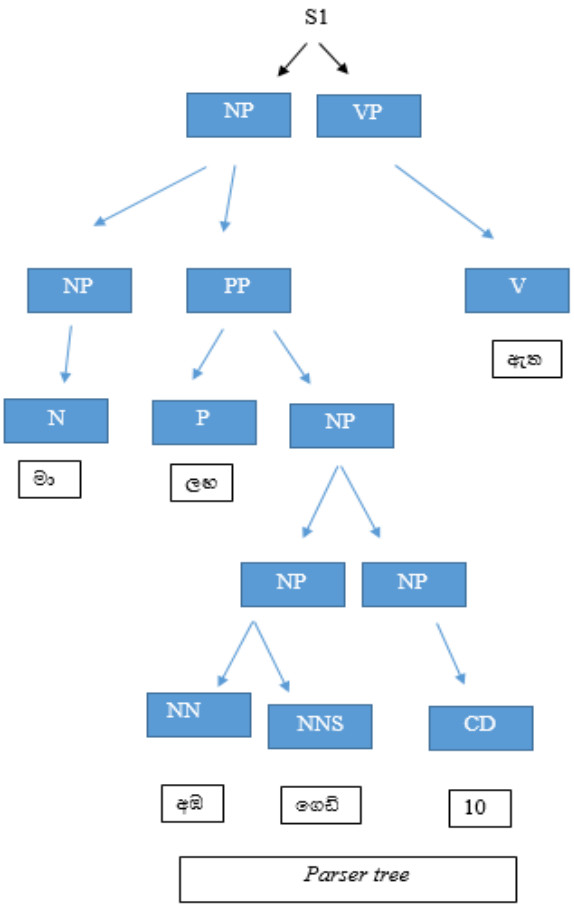


Figure 2 word breakdown with parser tree

Parser is a program, usually part of a compiler that receives input in the form of sequential source program instructions, every question is parsed to parser and breaks them up into nouns, verbs, and their attributes or options are extracted.

For our project we hope to use morphological parser [7] capable of analyzing and generating Sinhala verbs. Morphological analysis and generation plays a vital role in many applications related to natural language processing. Morphological parser is not like Stanford dependency parser which can only identify the verbs in Sinhala sentence so to identify the entities we have to use name entity recognition system.
The named entity recognition output is used to identify numbers and people etc..
Because entities are references to some object whose quantity is observed or changing throughout the problem.

Properties calculation

After identifying each candidate, we need to calculate properties that indicate that it may be a keyword. For that we use PPMI (Positive Point wise Mutual Information) to identify the word similarity

Word similarity is a measure of how semantically similar a pair of words is, with synonyms having the highest value. It is widely used for applications in natural language processing (NLP), information retrieval, and artificial intelligence.

Calculating PMI only requires simple statistics about two words, their marginal frequencies and their co-occurrence frequency in a corpus. More frequent words tend to have more senses, the synonyms under-weighted by PMI are often those with high frequency.so to identify more suitable keywords we hope to develop a new PMI metric.

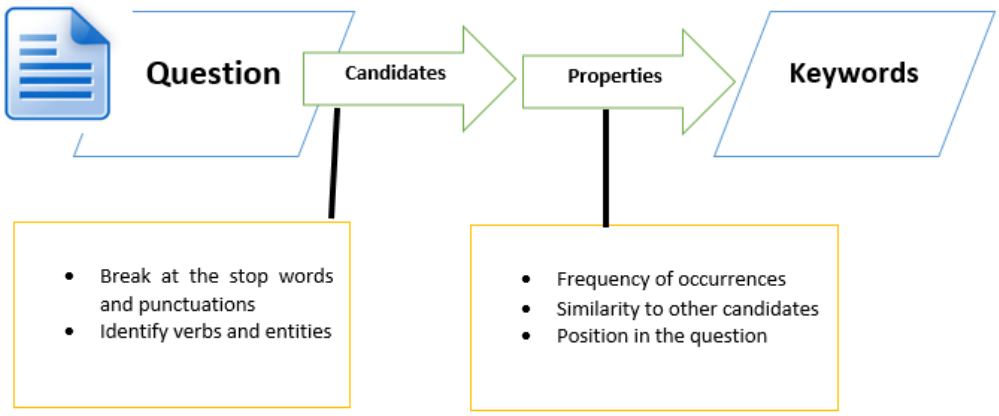


Figure 3 searching Keywords

3.2 Mathematical question identification

In this feature it expected that when the word problem in mathematics is provided, system identify in which category the mathematical problem fall in.

Mathematical question identification is done in parallel to key word identification. Question identification is done to make out what task the system should really perform. Since we are focusing on

- Addition problems
- Subtraction problems
- Calculating area.
- Currency
- Fractions
- Time calculations
- Decimal calculations
- Weight, length, volume and capacity calculations

Which are available in the grade 5 syllabus, it is a must to correctly identify under which topic the given question fall into since the method that must be used to solve the problem differs from each other depending on the topic.

When identifying the question there are four dimensions to be consider: level, perspective, focus, and time (Figure 03).

- What degree of certainty is indicated (LEVEL)
- Whose certainty is involved (PERSPECTIVE)
- What the object of certainty is (FOCUS)
- What time the certainty is expressed (TIME)

In here the task of learning to solve such mathematical problems by mapping the verbs in the problem text into categories that describe their impact on the world state. This step involves training a model to identify verb categories for sentences. For that extract the features by using 'Conditional Rational Fields' (CRF). Since the same word can appear in many forms it is crucial to have a morphological analysis. Sinhala is a

morphologically rich language. The Sinhala verb chiefly comprises of a verb root and a set of auxiliaries which enhance the meaning given in the verb root.

For instance, one stem could generate more than *45* inflected verb forms. That is why there is an urgent need for a parser that will use the morphological system to compute the part of speech and inflectional categories of Sinhala words.

To identify question, have to create a feature function f_i

In a CRF, each **feature function** is a function that takes in following components as inputs:

- a sentence s
- the position i of a word in the sentence
- the label $l_i$of the current word
- the label l_{i-1} of the previous word

Assign each feature function f_j a **weight** λ_j
Given a sentence s, we can now score a labeling l of s by adding up the weighted features over all words in the sentence

$$\text{Score } (l|s)= \sum_{j=1}^{m} \sum_{i=1}^{m} \lambda_i f_i \ (s, i, l_i , l_{i-1})$$

Finally, we can transform these scores into probabilities $p(l|s)$ between 0 and 1 by normalizing.

$$P(l|s)=\frac{\exp[score(l|S)]}{\sum l^1 \exp[score(l^1|s)]} = \frac{\exp[\sum_{j=1}^{m} \sum_{i=1}^{n} \lambda_j f_j(s,i,l_i,l_{i-1})]}{\sum_{l^1} \exp[\sum_{j=1}^{m} \sum_{i=1}^{n} \lambda_j f_i (s,i,l_i^1 l_{i-1}^1)]}$$

- $f_1(s, i, l_i, l_{i-1}) = 1$ if l_i=VERB, and the sentence ends in a question mark; 0 otherwise.
    - Again, if the weight λ2 associated with this feature is large and positive, then labeling that assign VERB to the first word in a question (e.g., "Is this a sentence beginning with a verb?") are preferred.

3.3 Identifying Mathematical Operation and generating an equation

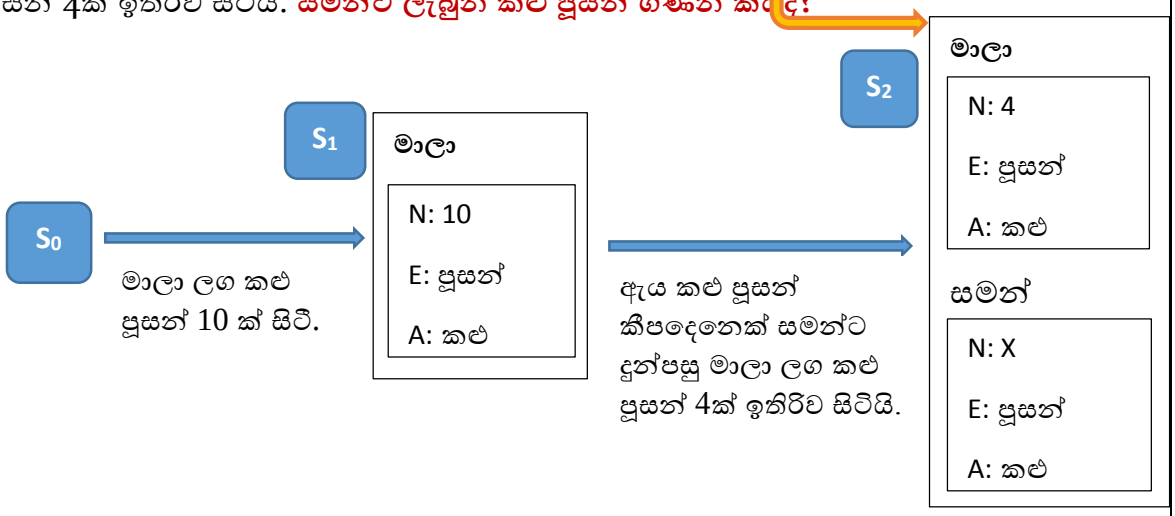
After doing Key words Identification and Question Identification the next most important part of the MAHOSHADA 2 system is Identifying the mathematical operation and generate an equation to solve the problem.

Arithmetic word problems begin by describing a partial world state, followed by simple updates or elaborations and end with a quantitative question. In MAHOSHADA 2 mainly focus on solving addition and subtraction problems. Solving the problem consists of two main steps: (1) progressing states based on verb categories in sentences and (2) forming the equation. After finding the consisting of entities (E), Containers (C), Attributes (A), relations(R) among entities and quantities, form the states $< s_1, s_2 \ldots s_T >$ by updating quantities in every container using learned verb categories. Match the entities and categories (An entity/category is matched if has the same head word and same set of attributes as an existing entity/category). If an entity or category cannot be matching, then a new one is created. For the matched entities, initializes or updates the values of the containers in the state.

The question is splitting into fragments where each fragment represents as a transition between two world states in which the quantities of entities update or observe. Using the learned verb categories solve the arithmetic problem by updating the states with the verb categories and find the relevant mathematical operation. It then forms an equation by comparing the quantities for containers matched between the two states. Then can solve the equation and return the absolute answer.

Question 01

මාලා ලග කළු පූසන් 10 ක් සිටී. ඇය කළු පූසන් කීපදෙනෙක් සමන්ට දුන්පසු මාලා ලග කළු පූසන් 4ක් ඉතිරිව සිටියි. **සමන්ට ලැබුන කළු පූසන් ගණන කීයද?**



N: Numbers E: Entities A: Attributes

Equation : 10 – X = 4

Solution : X = 6

Figure 4 arithmetic problem example

3.4 Neural network

A neural network is to be used which can be applied to increase the accuracy of the system. It will be a two hidden layer neural network so that the system gains universality which means the network can fit into any training data we provide. (Olah, 2014)

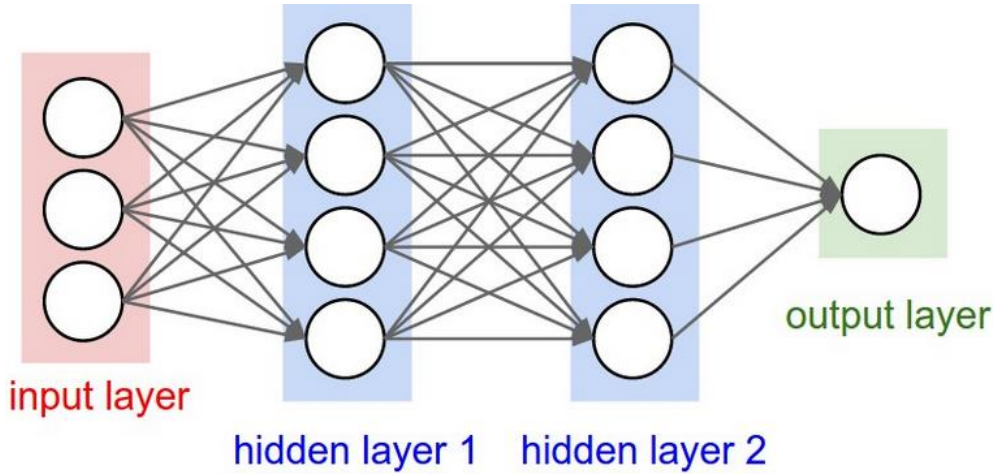


Figure 5 two hidden layer neural network

As shown below diagram there are 3 inputs for this neural network

- Outputs from keyword identification process
- Outputs from mathematical question identification process
- Outputs from mathematical operation identification process

Inside each hidden layer there will be an activation function that will generate the output of that layer. Most relevant components to generate the solution of the problem will be extracted through this activation function. The outputs that are generated by the activation function will have to be threshold. Thresholding will convert the answers of activation function into 1 or 0.

Only the outputs which hold '1' will be sent to the next layer.

$$\text{output} = \begin{cases} 0 & \text{if } \sum_j w_j x_j \leq \text{ threshold} \\ 1 & \text{if } \sum_j w_j x_j > \text{ threshold} \end{cases}$$

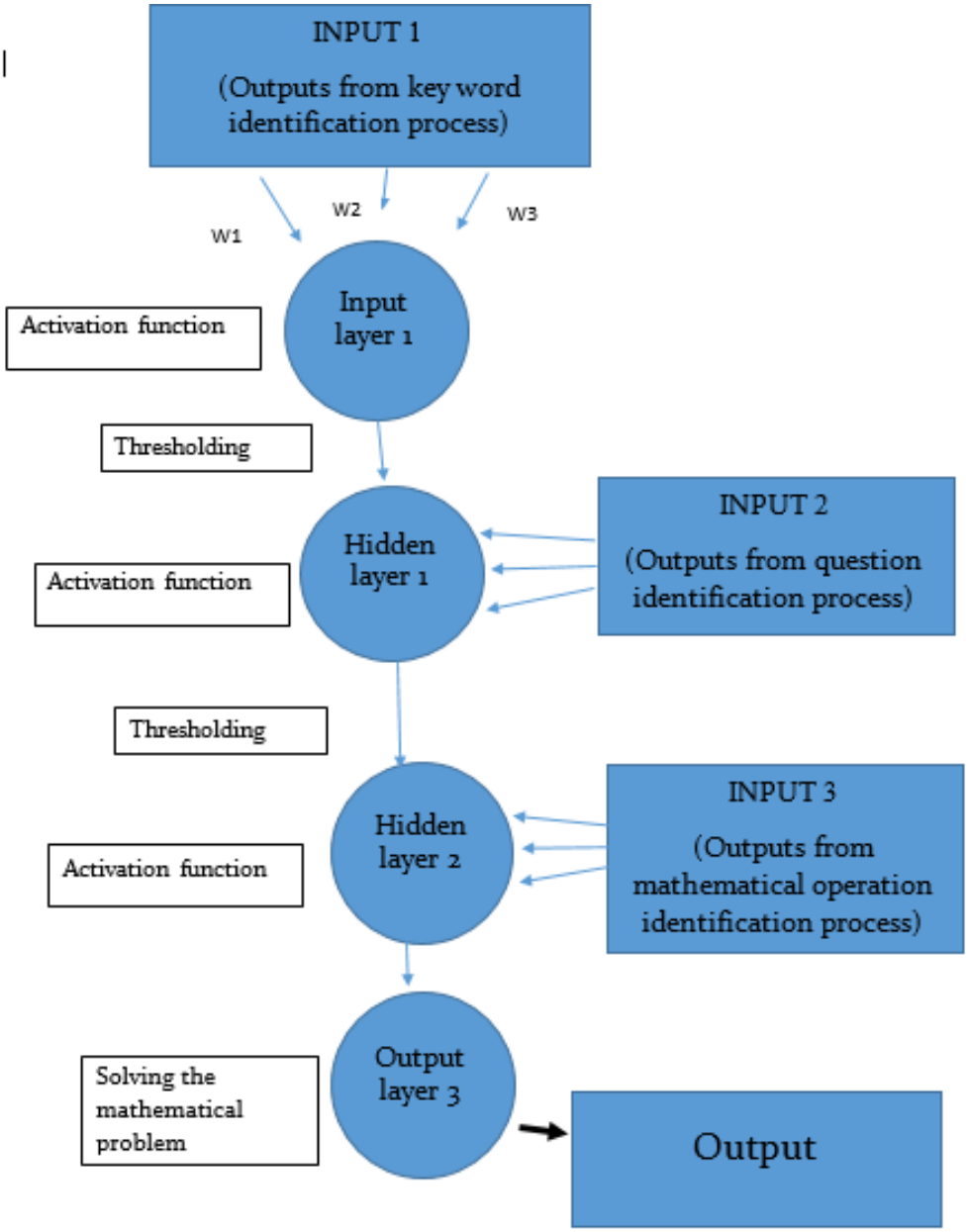


Figure 6 Overview of neural network

In developing the neural network following main design steps can be identified.

1. Collect data
2. Create the network
3. Configure the network
4. Initialize the weights and biases
5. Implement an activate function

6. Train the network
7. Validate the network
8. Use the network (Tulleken., 2009)

3.4.1 Configure the network

After a neural network has been created, it must be configured. The configuration step consists of examining input and target data, setting the network's input and output sizes to match the data, and choosing settings for processing inputs and outputs that will enable best network performance. The configuration step is normally done automatically, when the training function is called.

3.4.2 Initialize the weights and basics

This function must take in a maximum weight, a width and height, and return a matrix of the given width and height

3.4.3 Implement an activate function

Sigmoid type activation function will be implemented. In this case some notation will be developed to review some known facts.

3.4.4 Train the network

'Online training' will be performed in the proposed network, in which weights and biases are updated for each and every problem. Same word may have different priorities in different problems. So assigning the same weight for a particular word in every problem may not be appropriate. It should be changed according to the problem.

4. Description of personal and facilities

4.1 Task breakdown

Member	Description
De Silva K.C.E IT12143214	**Identify Keywords** Develop a new keyword extraction technique .Identify verbs and entities (candidates) in the question by using morphological parser and name entity recognition analysis. After identifying each candidate calculate properties that indicate that it may be a keyword. Use PPMI (Positive Point wise Mutual Information) to identify the word similarity
Raddella A.M IT12082148	**Question identification** Create algorithm to identify the mathematical problem. This step involves training a model to identify verb categories for sentences. For that Conditional random field algorithms will be used.
Ekanayake E.M.R.S IT12142774	**Identify and perform mathematical operation** Develop a method to find mathematical operation using relevant key words and verb categories. After finding the consisting of entities, Containers, Attributes, relations among the entities and quantities, mapping the algebraic problem in to an equation. Solving the equation and get the final answer.
Chathurika W.M.T. IT12142538	**Neural Network** Develop the Neural Network for the proposed system. This is a large scale neural network which consists of 2 hidden layers, input layer and output layer. Outputs from other 3 functions are inserted as inputs to the neural network in separate layers. Final answer will be generated at the output layer.

Table 1 Task breakdown

4.2 Gantt chart

4.3 Nonfunctional Requirements

4.3.1 Performance Requirements

The only way in which systems will meet their performance targets is for them to be specified clearly and unambiguously. It is a simple fact that if performance is not a stated criterion of the system requirements then the system designers will generally not consider performance issues. The performance of the product must be to the highest level, since lot of mathematical questions are handled through the system. Since the system consists of lot sub modules coming up with a suitable design specifically concentrating on performance wise is very important.

4.3.2 Safety Requirements

Safety consistent with mission requirements, is designed into the software in a timely, cost effective manner. The system will always be confirmed to run properly and give the correct answer effectively, therefore there is no risk of any data losses. Further data retrieval is also efficient.

4.3.3 Security Requirements

Security is often an afterthought during software development. Realizing security early, especially in the requirement phase, is important so that security problems can be tackled early enough before going further in the process and avoid rework. According to the user privileges of the system, user can perform his /her relevant tasks which are assigned to them by the system.

4.4 Software Requirements and Hardware Requirements

Needed Resources to the system,

- Server Computer - core i5 2.6 GHz
- Ram - 4 GB RAM
- Hard Drive - 500 GB hard disk drive
- VGA - 1GB
- Linux fedora
- VMware Workstation
- Adobe Photoshop
- MS project
- MS Office

Above mentioned hardware components and software components will be the main needed components to develop and to use the system.

5. Budget and Budget Justification

Description	**Price (Rs)**
1. Travel and Expenses	600.00
2.Documentations Expenses	1000.00
2.Communication Expenses	500.00
4.Consultancy Expenses	-
Subtotal of the Hardware cost	0.00
Linus OS	0.00
Total Estimation	**Rs. 2100 .00**

Table 2 Budget

6. Conclusion

Question answering is an important approach in Natural Language Processing (NLP). In this proposed mathematical word problem solving system we encourage grade 5 students to learn mathematics in their native language. Since the system is to be created with appropriate interfaces that attract children we hope the system would be a productive one for students in grade 4-5.

Normally Sri Lankan education is a teacher centered paradigm. Within that frame Knowledge is transmitted from professor to students and students are not actively involved. Under that situation a better method is needed to get the student out of the ordinary frame and let the students experience the students-centered paradigm. That leads the student to practice active learning and learn from their own mistakes. To achieve that goal this system will provide simulations for the students on solving the given mathematical problem. Therefor students can do self-learning through the system.

Most of the time mathematics is considered to be a difficult subject. Grade 5 mathematics is the foundation for the higher level mathematical theories. Majority of the Sri Lankan students are learning in the 'Sinhala' language. So it is important to make it available for them to study such a difficult to learn subject in their mother tongue. On that purpose 'Mahoshadha 2' is to be developed to understand and solve mathematical problems in Sinhala language.

We expect that the system will be up to quality standards which will make the system preform the given task efficiently and correctly.

7. Appendix

NLP-natural language processing is a field of computer science, artificial intelligence, and computational linguistics concerned with the interactions between computers and human (**natural**) languages. As such, **NLP** is related to the area of human–computer interaction

PMI – Pointwise mutual information (PMI), or point mutual information, is a measure of association used in information theory and statistics. In contrast to mutual information (MI) which builds upon PMI, it refers to single events, whereas MI refers to the average of all possible events.

PPMI- positive pointwise mutual information

Positive value of the pointwise mutual information

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