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# Machine Comprehension using Improved Bi-Directional Attention Flow Network

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**Sijun He**  
Stanford University  
sijunhe@stanford.edu

**Jiajun Sun**  
Stanford University  
jiajuns@stanford.edu

**Mingxiang Chen**  
Stanford University  
ming1993@stanford.edu

## Abstract

## 1 Introduction

Machine Comprehension (MC) and Question Answering (QA) were increasingly popular in the past few years. Almost all human knowledge are recorded as text. Just like what we did in school doing reading comprehension questions, extracting information from a specific piece of context would enable artificial intelligence to get to a higher level. Different kinds of natural language processing structures such as Gated Recurrent Unit (GRU) and Long Short Term Memory (LSTM) has been introduced.

These years, there are several QA database that has been released. In this paper, we describe a way using an improved version of bi-directional attention flow for the task of question answering using recently published Stanford Question Answering Dataset (SQuAD) which consisted of approximately 100K question-answer pairs with the context.

The objective of the study was to extract the answer for a given question from a certain context. The model was built based on the previous hierarchical multi-stage bi-directional attention flow (BiDAF) model (Minjoon Seo et al. 2017) while evaluating the correctness using corresponding F1 score and exact-match (EM) score.

## 2 Models

Our machine learning model (Figure 1) is hierachical multi-stage with 5 layers.

### 2.1 Word Embedding Layer

The word embedding layer maps each individual word into a high-dimension vector space. It is a set of pretrained GloVe word vectors using datasets provided by Wikipedia 2014 and Gigaword 5. The dimensionality of the vectors are 100.

### 2.2 Contextual Embedding Layer

In this layer, we introduced a Bi-directional Long Short-Term Memory (BiLSTM) network as our encoding layer. Contexts and questions will be fed into the network seperately, while the output from

each state will all be recorded. Note that the output of which will be 2d-dimension vectors (where d is 100 in our model) due to the concatenation of two output for each direction of the network.

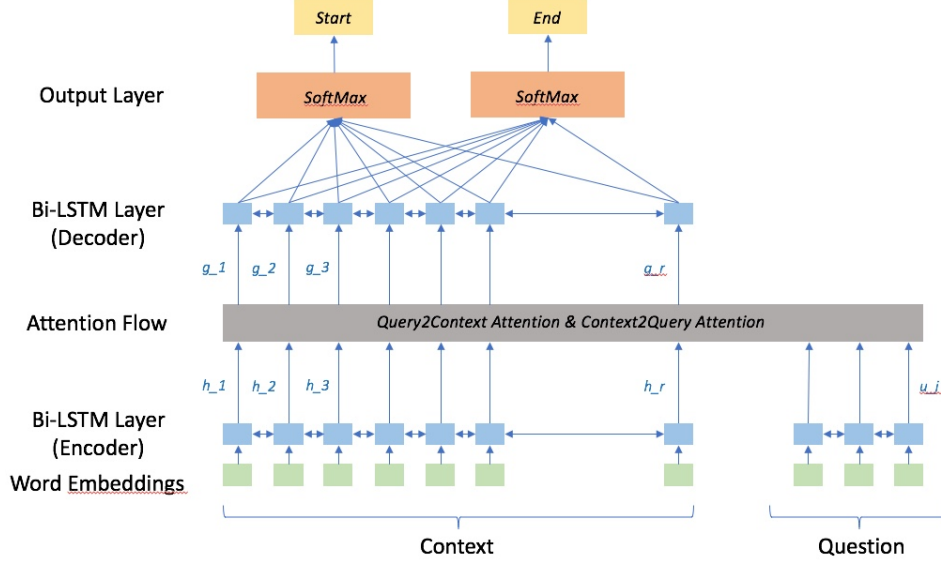


Figure 1: Bi-Directional Attention Flow Model

### 2.3 Attention Flow Layer

The attention layer is introduced to link together the information from the question and the information given by the context. It tells us how important it is that we should pay attention to each word vector in the text (both contexts and questions). The input of this layer is contextual vector of the context  $H$  and the question  $U$ .

In this layer, the attention is calculated from the similarity matrix of  $H$  and  $U$  as follow:

$$S_{ij} = \alpha(H_{:,t}, U(:,j))$$

where  $S_{ij}$  indicates the similarity of the word  $i$  in the context and the word  $j$  in the query, and  $\alpha$  is the bilinear factor which is defined as

$$\alpha(h, u) = h^T W_{bi} u$$

$W$  is a trainable matrix of  $R^{2d \times 2d}$  (Chen et al. 2016).

#### 2.3.1 Context-to-query Attention

The context-to-query attention indicates the weight of each word in the query considering the given context. The attention weight is computed as follow

$$weight = SoftMax(S_{i,:})$$

so that the query vectors turn out to be

$$\hat{U} = \sum_j a_{ij} U_{:,j}$$

### 2.3.2 Query-to-context Attention

The query-to-context attention indicates the weight of each context word considering the given query. Similar to what we did in context-to-query attention, the attention weights are calculated from

$$b = \text{SoftMax}(\max_{col}(S))$$

and

$$\hat{H} = \sum_t b_t H_{:t}$$

Then we combined three vectors as the yield  $G$ , where  $\beta$  is a trainable vector of  $R^{8d \times T}$

$$G = \beta(H, \hat{U}, \hat{H})$$

## 2.4 Modeling Layer

The input of the modeling layer (decoding layer) encrypts the information of the context together with some information from the query. So that when we pass the tensor to a bi-LSTM network, similar to what we did in the contextual embedding layer, the output would be a matrix of  $R^{2d \times T}$ , where  $T$  indicates the number of context in the dataset.

## 2.5 Output Layer

In this layer, we provides the answer to questions by calculating the probability for each position in the context as the start and the end of the answer with SoftMax. However, in some situations, though very rare, we would flip over the start and ending labels if the ending predicted maybe even appears earlier than the start in the context. It would be discussed more in detail in section 4.

## 3 Headings: first level

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### 3.1 Headings: second level

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## 4 Citations, figures, tables, references

These instructions apply to everyone, regardless of the formatter being used.

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Citations within the text should be numbered consecutively. The corresponding number is to appear enclosed in square brackets, such as [1] or [2]-[5]. The corresponding references are to be listed in the same order at the end of the paper, in the **References** section. (Note: the standard BibTeX style

unsorted produces this.) As to the format of the references themselves, any style is acceptable as long as it is used consistently.

As submission is double blind, refer to your own published work in the third person. That is, use “In the previous work of Jones et al. [4]”, not “In our previous work [4]”. If you cite your other papers that are not widely available (e.g. a journal paper under review), use anonymous author names in the citation, e.g. an author of the form “A. Anonymous”.

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Indicate footnotes with a number<sup>1</sup> in the text. Place the footnotes at the bottom of the page on which they appear. Precede the footnote with a horizontal rule of 2 inches (12 picas).<sup>2</sup>

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All artwork must be neat, clean, and legible. Lines should be dark enough for purposes of reproduction; art work should not be hand-drawn. The figure number and caption always appear after the figure. Place one line space before the figure caption, and one line space after the figure. The figure caption is lower case (except for first word and proper nouns); figures are numbered consecutively.

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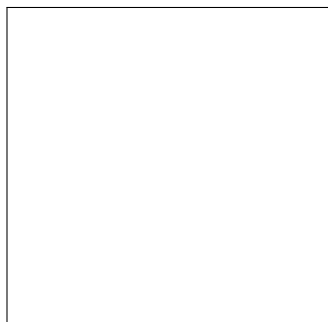


Figure 2: Sample figure caption.

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Place one line space before the table title, one line space after the table title, and one line space after the table. The table title must be lower case (except for first word and proper nouns); tables are numbered consecutively.

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<sup>1</sup>Sample of the first footnote

<sup>2</sup>Sample of the second footnote

Table 1: Sample table title

PART	DESCRIPTION
Dendrite	Input terminal
Axon	Output terminal
Soma	Cell body (contains cell nucleus)

### Acknowledgments

Use unnumbered third level headings for the acknowledgments. All acknowledgments go at the end of the paper. Do not include acknowledgments in the anonymized submission, only in the final paper.

### References

References follow the acknowledgments. Use unnumbered third level heading for the references. Any choice of citation style is acceptable as long as you are consistent. It is permissible to reduce the font size to ‘small’ (9-point) when listing the references. **Remember that this year you can use a ninth page as long as it contains *only* cited references.**

[1] Danqi Chen., Jason Bolton. & Christopher D. Manning. (2016) A thorough examination of the cnn/daily mail reading comprehension task. *arXiv:1606.02858*

[1] Alexander, J.A. & Mozer, M.C. (1995) Template-based algorithms for connectionist rule extraction. In G. Tesauero, D. S. Touretzky and T.K. Leen (eds.), *Advances in Neural Information Processing Systems 7*, pp. 609-616. Cambridge, MA: MIT Press.

[2] Bower, J.M. & Beeman, D. (1995) *The Book of GENESIS: Exploring Realistic Neural Models with the GEneral NEural Simulation System*. New York: TELOS/Springer-Verlag.

[3] Hasselmo, M.E., Schnell, E. & Barkai, E. (1995) Dynamics of learning and recall at excitatory recurrent synapses and cholinergic modulation in rat hippocampal region CA3. *Journal of Neuroscience* **15**(7):5249-5262.