

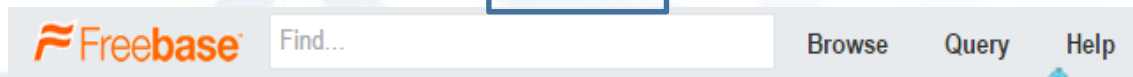
# Employing External Rich Knowledge for Machine Comprehension

中国科学院自动化研究所  
模式识别国家重点实验室

王炳宁 郭尚敏 刘康 赵军

# What is machine comprehension?

QA



Baidu 百度

百度一下

WIKIPEDIA

English

The Free Encyclopedia  
5 077 000+ articles

日本語

フリー百科事典  
1 001 000+ 記事

Русский

Свободная энциклопедия  
1 289 000+ статей

Italiano

L' enciclopedia libera  
1 252 000+ voci

中文

自由的百科全书  
863 000+ 条目

Español

La enciclopedia libre  
1 233 000+ artículos

Deutsch

Die freie Enzyklopädie  
1 907 000+ Artikel

Français

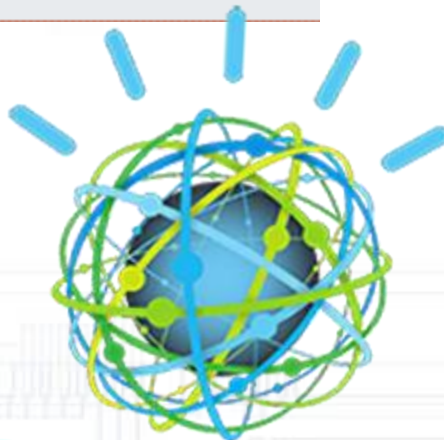
L' encyclopédie libre  
1 723 000+ articles

Português

A enciclopédia livre  
909 000+ artigos

Polski

Wolna encyklopedia  
1 154 000+ haseł



IBM Watson

VS.

MC

K5 Learning

Grade 1 Reading Comprehension Worksheet  
Read the passage. Then answer each question.

## THE BOAT PARADE

The boats are floating along the lakeshore. It is the summer boat parade.

There are motor boats, rowboats and sailboats.

Jessica's favorite is the yellow motor boat with the flag. The rowboat decorated with flowers is Lisa's favorite. Tony likes the purple sailboat.

The boats float by one at a time. The people on the boats wave at the crowds. The crowds cheer the boats.

The boat parade is so much fun to watch. It

### Answer the Questions:

- Where are the boats floating?
- What kind of boats are there?
- What is Lisa's favorite boat?
- What is the best part of summer?

Online reading & math for K-5

Name: \_\_\_\_\_

Main Idea and Details  
Sequence WEEK 7  
DAY 5

READ THE PASSAGE Notice the order of events.

### Liam Baby-sits

Gus and Bret started crying as soon as their mother closed the door. They didn't want her to leave. Liam, their baby sitter, tried to distract the boys. "Let's play hide-and-seek. You guys hide and I'll count to ten. Then I'll try to find you." Liam found Gus under a chair and Bret behind a door. They played over and over again. Each time, the two boys hid in the same places. Finally, Liam could not stand to play one more time. "Let's take the dog for a walk," he said.

Big Bertha pulled her leash and Liam, too. Gus ran one way and Bret dashed the other. Liam had to act fast. He decided to bribe the boys into behaving. "Whoever walks back to the house with me can have a snack!" Liam shouted.

At home, the boys chomped on some cookies and got ready for a nap. They demanded a story. Liam told them the story of the little red hen over and over again. When Mrs. Hobbs returned home, she found three sleeping boys.

SKILL PRACTICE Read the question. Fill in the bubble next to the correct answer.

- What is the story mainly about?
  - Ⓐ three boys playing together
  - Ⓑ a boy's baby-sitting problems
  - Ⓒ two little boys playing with their sitter
  - Ⓓ a mom leaving her boys with a sitter
- What two things does Liam do first with the boys?
  - Ⓐ play a game, go for a walk
  - Ⓑ go for a walk, eat a snack
  - Ⓒ eat a snack, hear a story
  - Ⓓ walk the dog, eat a snack
- When does Liam bribe the boys?
  - Ⓐ after they cry for their mom
  - Ⓑ after they play hide-and-seek
  - Ⓒ when they demand a story
  - Ⓓ when they run outside
- What do Gus and Bret do when they play hide-and-seek?
  - Ⓐ They count to 10.
  - Ⓑ They cry and cry.
  - Ⓒ They both hide under a chair.
  - Ⓓ They hide in the same places each time.

STRATEGY PRACTICE Tell a partner three things Liam did with the boys in the order that he did them.

START

Natural Language Question Answering System

ask START a question

Ask Question >

Document

One night I was at my friend's house where he threw a party. We were enjoying our dinner at night when all of a sudden we heard a knock on the door. I opened the door and saw this guy who had scar on his face. (.....)As soon as I saw him I ran inside the house and called the cops. The cops came and the guy ran away as soon as he heard the cop car coming. We never found out what happened to that guy after that day.

Question

1: *What was the strange guy doing with the friend?*

Candidate answers

- A) enjoying a meal
- B) talking about his job
- C) talking to him
- \*D) trying to beat him

2: *Why did the strange guy run away?*

- \*A) because he heard the cop car
- B) because he saw his friend
- C) because he didn't like the dinner
- D) because it was getting late

**Mctest:** Richardson M, Burges C J C, Renshaw E. MCTest: A Challenge Dataset for the Open-Domain Machine Comprehension of Text //EMNLP. 2013, 1: 2.

分为MC160和MC500

Split	MC160		MC500	
	Documents	Questions	Documents	Questions
Train	70	280	300	1200
Dev	30	120	50	200
Test	60	240	150	600

## Other Resources:

Document: 150-300 words  
Question: About 10 words

Facebook : bAbI<sup>1</sup>  
Google Deepmind: CNN and Daily Mail articles<sup>2</sup>  
Facebook: CBTest<sup>3</sup>  
Stanford: ProcessBank <sup>4</sup>

[1] Weston J, Bordes A, Chopra S, et al. Towards ai-complete question answering: A set of prerequisite toy tasks[J]. arXiv preprint arXiv:1502.05698, 2015.

[2] Hermann K M, Kocisky T, Grefenstette E, et al. Teaching machines to read and comprehend[C]//Advances in Neural Information Processing Systems. 2015: 1684-1692.

[3] Hill F, Bordes A, Chopra S, et al. The Goldilocks Principle: Reading Children's Books with Explicit Memory Representations[C]// ICLR. 2016.

[4] Berant J, Srikumar V, Chen P C, et al. Modeling Biological Processes for Reading Comprehension[C]//EMNLP. 2014.



由于MCtest数据集较小，基于大数据的深度学习技术很难应用到其中去。以往的方法往往是依靠一些现有的自然语言处理工具抽取文档特征然后以此对文档进行建模。

Lexical Matching

Discourse Relation

Syntactic Parsing

Dependency Parsing

Word Representation Similarity

.....

这些特征直观清楚，但是构建这些特征费时费力。并且在实际中虽然能对阅读理解的一部分问题有效的处理，但是特征工程的方法相对于最基本的非监督的基线系统的提升非常有限。

和传统问答系统一样，标准阅读理解也可以分为两部分。即答案选择（Answer Selection）和答案生成（Answer Generation）

答案选择（Answer Selection）：根据问题，一系列文档或者句子中选择能回答这个问题的片段。

答案生成（Answer Generation）：根据问题和上一步选择出的片段生成出最后的答案。

One night I was at my friend's house where he threw a party. We were enjoying our dinner at night when all of a sudden we heard a knock on the door. I opened the door and saw this guy who had scar on his face. (.....)As soon as I saw him I ran inside the house and called the cops. The cops came and the guy ran away as soon as he heard the cop car coming. We never found out what happened to that guy after that day.

1: *What was the strange guy doing with the friend?*

- A) enjoying a meal
- B) talking about his job
- C) talking to him
- \*D) trying to beat him

## Proposed Method

Document:  $D$

Document sentences:  $\{s_1, \dots, s_n\}$

Question:  $q$

Candidate Answers:  $\{a_1, \dots, a_4\}$

$$p(a|q, D) = \underbrace{p(S|q, D)}_{\text{答案选择}} \underbrace{p(a|q, S)}_{\text{答案生成}}$$

答案选择    答案生成

One night I was at my friend's house where he threw a party.  
We were enjoying our dinner at night when all of a sudden we heard a knock on the door.  
(.....)  
A few seconds later I heard a noise from outside and when I ran outside I saw that the strange guy was trying to beat my friend.  
As soon as I saw him I ran inside the house and called the cops.  
The cops came and the guy ran away as soon as he heard the cop car coming.  
We never found out what happened to that guy after that day.

$(q, S)$   
生成

$$\mathbf{X} = [\mathbf{x}_1, \mathbf{x}_2, \dots, \mathbf{x}_n]$$

$$\mathbf{h}_t = \sigma(\mathbf{W}_{ih}\mathbf{x}_t + \mathbf{W}_{hh}\mathbf{h}_{t-1} + \mathbf{b}_h)$$

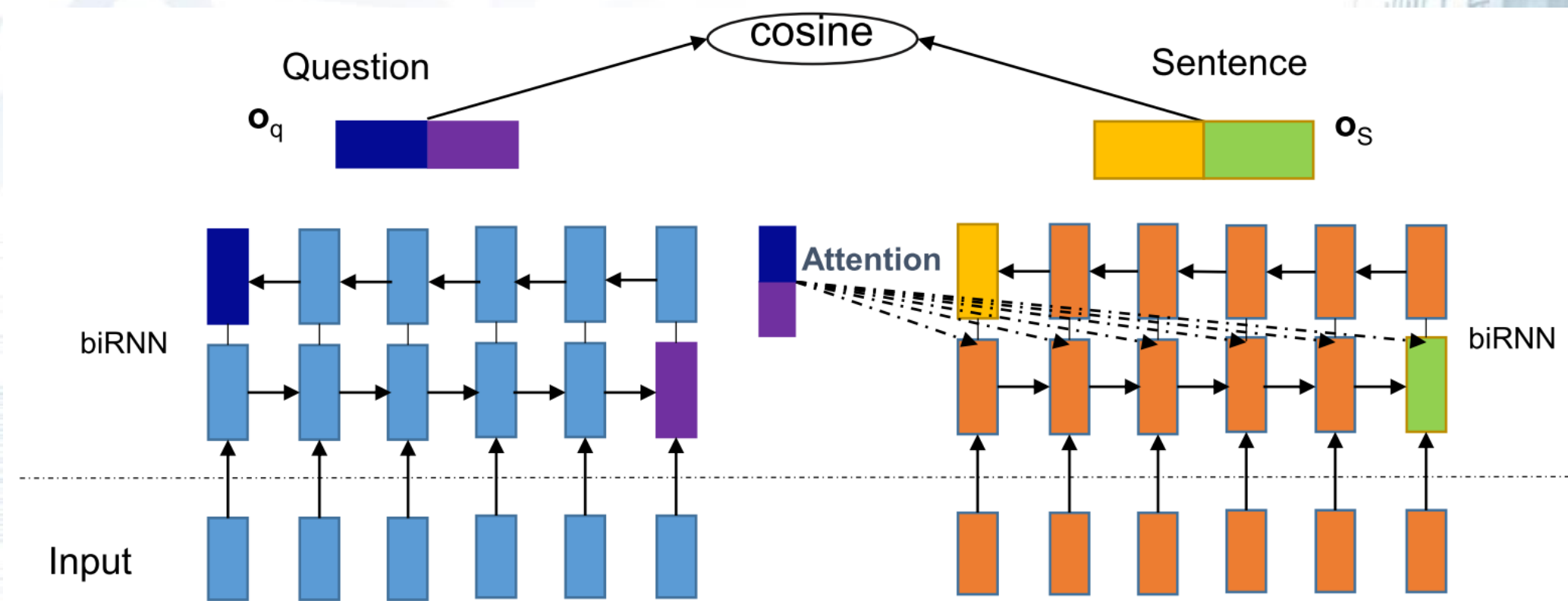
$$s_t \propto \mathbf{h}_t^T \mathbf{W}_{qo} \mathbf{h}_n^q$$

$$\tilde{\mathbf{h}}_t = s_t \mathbf{h}_t$$

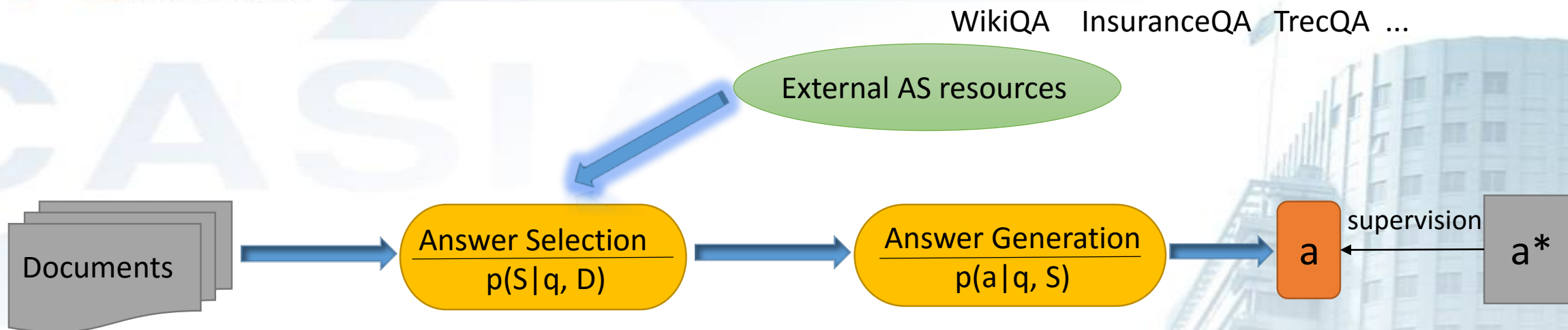
*What was the strange guy doing with the friend?*



Answer selection model architecture



# Proposed Method



$$L_{AS}(q, D) = \sum_{s \in D} P(s|q, D; \theta_{RNN}) \log Q(s|q, D)$$

在外部的Answer selection数据  
上训练的一个模型

After we had dinner the strange guy asked my friend to come outside because he wanted to talk to him. A few seconds later I heard a noise from outside and when I ran outside I saw that the strange guy was trying to beat my friend. I ran towards him and asked him to leave our house. He left the house but after half an hour he came back and this time he was dressed up as superhero and he also had a sword. As soon as I saw him I ran inside the house and called the cops. The cops came and the guy ran away as soon as he heard the cop car coming. We never found out what happened to that guy after that day.

Q: Why did the strange guy run away?

- A) because he heard the cop car
- B) because he saw his friend
- C) because he didn't like the dinner
- D) because it was getting late



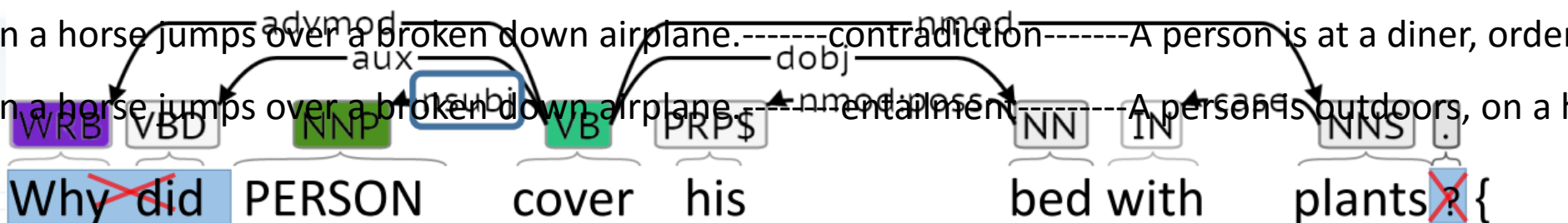
The strange guy run away beacuse he heard the corp car

## Recognizing Textual Entailment-RTE

A person on a horse jumps over a broken down airplane.-----neutral-----A person is training his horse for a competition.

A person on a horse jumps over a broken down airplane.-----contradiction-----A person is at a diner, ordering an omelette.

A person on a horse jumps over a broken down airplane.-----entailment-----A person is outdoors, on a horse.



candidate answer: {Because he wanted a green bed}

**Dataset:**

SNLI SICK ...

9 rules to transform a question and answer candidate to a statement



Combine External RTE knowledge with robust lexical feature

$$P(a|s,D) = [\beta P(s_q|s; \theta_1) + (1 - \beta) P(s_q|s; \theta_{RTE})]$$

lexical matching

RTE Score

$$\beta = \text{similarity}(s_q^-, s)$$

$s_q^-$  代表我们将候选陈述句中的答案替换为一个符号ANSWER

similarity 是我们设计的一个词项匹配相似度，主要由n-gram constituency match, dependency match构成，用以判断两个句子之间是否有明显的词项联系

$$P(a|q, s; \theta_1)$$

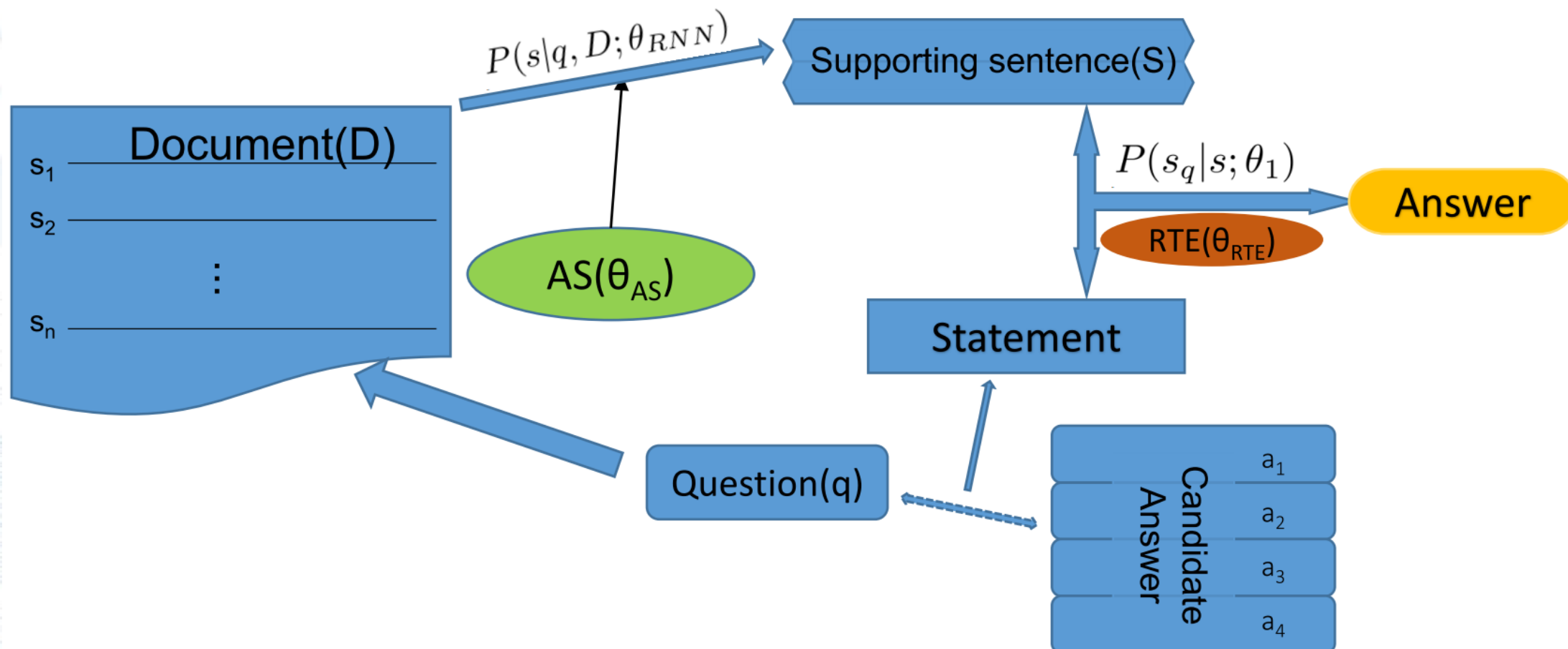
我们采用如下的词项特征：

- bag-of-words matching
- dependency root matching
- constituency sub-tree matching
- dependency path matching
- name entity matching
- digit matching

$$P(a_{ij}^*|q_{ij}) = P(s|q, D; \theta_{RNN}) \\ * [\beta P(s_q|s; \theta_1) + (1 - \beta)P(s_q|s; \theta_{RTE})]$$

$$L(\theta_{+AS+RTE}; D_{train}) \\ = \log \sum_{i=1}^{|D_{train}|} \sum_{j=1}^{|Q|} [P(a_{ij}^*|q_{ij}) + \eta L_{AS}(q_{ij}, D_i)] \\ - \lambda g(\theta_{+AS+RTE})$$

$g$ 是正则化参数，我们使用elastic net作为正则函数





## Preprocess and External Knowledge

我们将MCTest中文档进行指代消解，将文中的代词用命名实体代替。

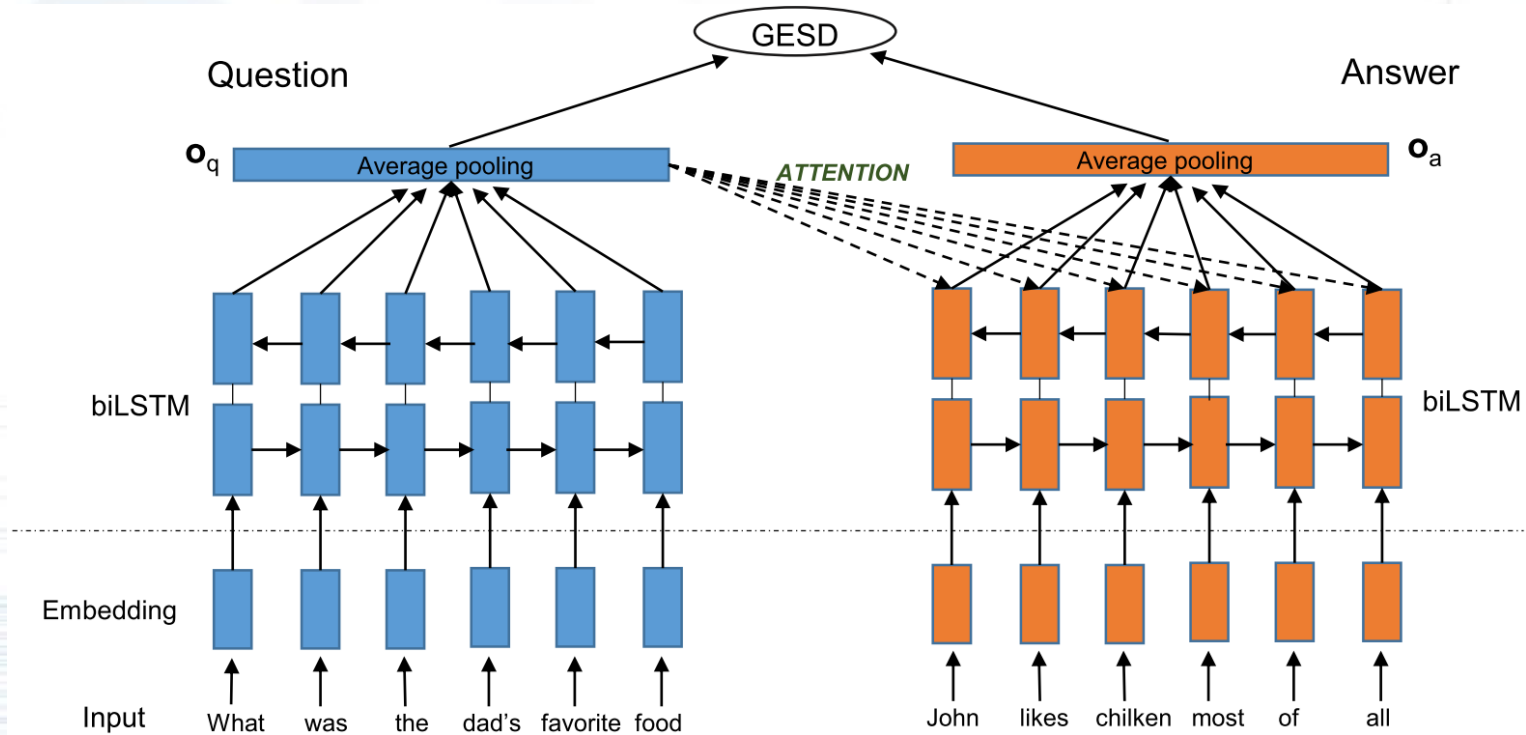
对于外部的答案选择资源（Answer selection）资源，我们使用WikiQA数据集，这个数据集基于维基百科，拥有将近2000个问题和3万个候选答案句子。  
我们将wikiQA中所有的命名实体全部替换成其命名实体属性：

Barack Obama-> PERSON

The russia-> ORGANIZATION

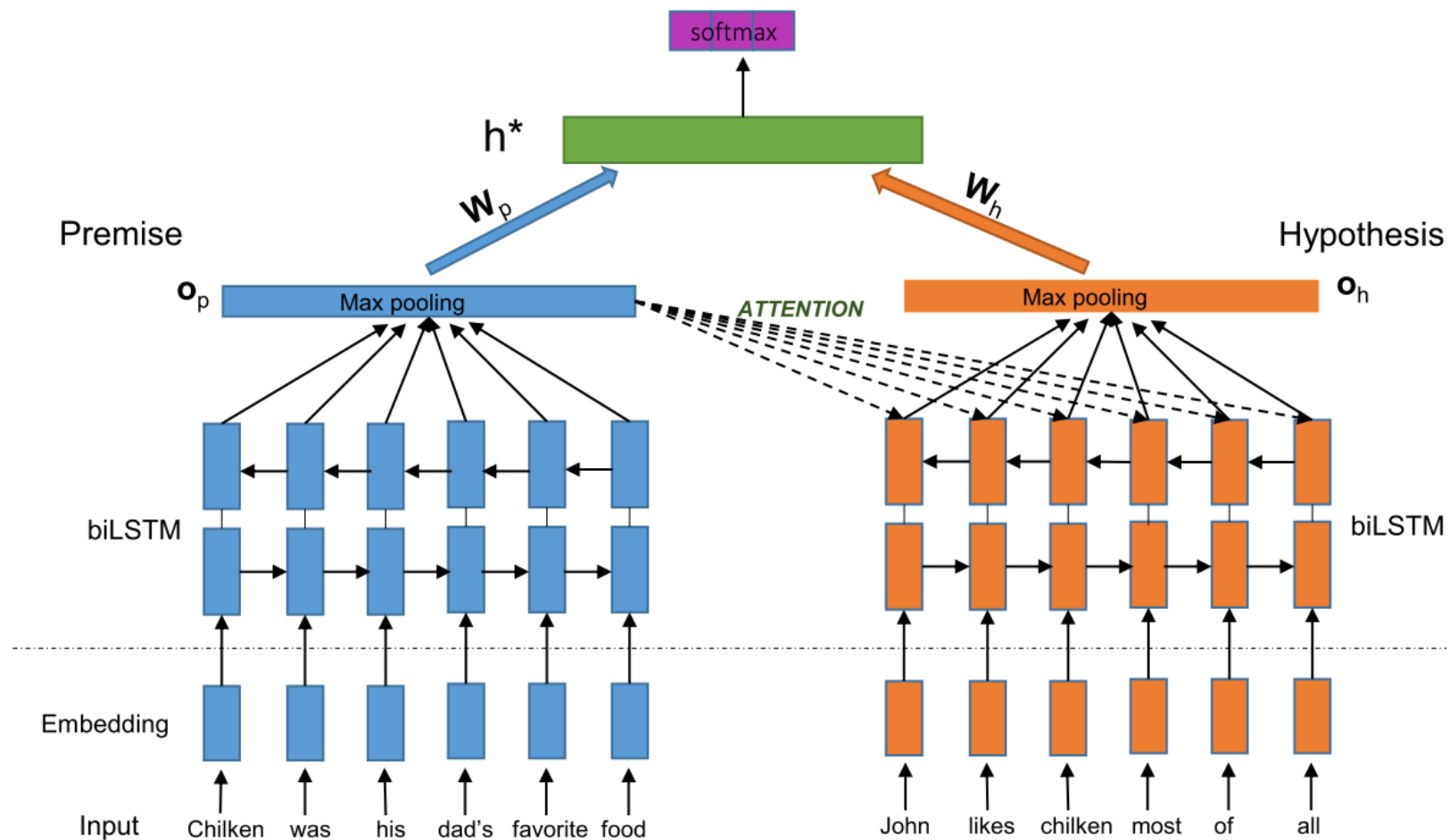
对于外部的文本蕴涵推理（RTE）资源，我们选用斯坦福大学最新发布的超大规模语言推理数据集（SNLI）其中的训练集有50万对句子。

## External Answer Selection model



$$GESD(x, y) = \frac{1}{1 + ||x - y||} \cdot \frac{1}{1 + \exp(-\gamma(xy^T + c))}$$

External RTE model



## External Model Result

	Answer Selection		RTE
	MAP	MRR	Accuracy
State of the Art	0.6921	<b>0.7108</b>	<b>0.835</b>
Our method	<b>0.6936</b>	0.7094	0.829

Yin W, Schütze H, Xiang B, et al. ABCNN: Attention-Based Convolutional Neural Network for Modeling Sentence Pairs[J]. TACL . 2016.

Rocktäschel T, Grefenstette E, Hermann K M, et al. Reasoning about Entailment with Neural Attention[C]. ICLR . 2016.



## Experiment Result

System	MC160			MC500		
	One	Multiple	All	One	Multiple	All
Sliding Window	64.73	56.64	60.41	58.21	56.17	57.09
Sliding Window+Word Distance	76.78	62.50	67.50	64.00	57.46	60.43
Sliding Window+Word Distance+RTE	76.78	62.50	69.16	68.01	59.45	63.33
[Kapashi and Shah, 2015]	-	-	36.0	-	-	34.2
[Narasimhan and Barzilay, 2015]	82.36	65.23	73.23	68.38	59.90	63.75
[Wang and McAllester, 2015]	84.22	67.85	75.27	72.05	67.94	69.94
[Smith <i>et al.</i> , 2015]	78.79	<b>70.31</b>	75.77	69.12	63.34	65.43
[Sachan <i>et al.</i> , 2015]	-	-	-	67.65	<b>67.99</b>	67.83
without External Knowledge( $\beta = 1, \eta = 0$ )	40.39	37.94	39.08	38.40	33.13	31.33
without External AS knowledge( $\eta = 0$ )	41.07	40.63	40.83	49.63	28.05	32.83
without External RTE knowledge( $\beta = 1$ )	74.11	64.06	68.75	57.72	50.91	53.00
Final Model	<b>88.39</b>	64.84	<b>75.83</b>	<b>79.04</b>	63.51	<b>70.96</b>

# Thank you!