Key-Value Memory Networks for Directly Reading Documents (EMNLP16)

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Question Answering From Text

Goal:

- Read documents and answer questions about them

Challenges for Raw Text:

- Information is unstructured

- Answers are indirectly or ambiguously expressed

- Scattered across multiple documents

Work-around: Knowledge Bases?

- Large data sources: e.g. FreeBase, Dbpedia, etc

- Have been effective tools for QA

Poor performance.

But … intrinsically limited?

Knowledge Bases vs Text

Limitations of Knowledge Base Learning:

- Availability

- Knowledge bases are often incomplete

- Expressiveness

Advantages of Raw Text Learning:

- Plenty of data

- Lossless

More difficult to interpret

Our Work

Hypothesis:

Intuitively, systems answering directly from text should be more powerful than those using KBs. They should be able to address more complex tasks.

Problem…

In the current state of the art, they are not as accurate, even on basic tasks.

This work tries to close that gap.

Contributions

WikiMovies

- A new dataset for QA in the movies domain

- Raw text + Knowledge Base formats side by side

- A useful analysis tool for comparing methods

Key-Value Memory Networks

- A new, more effective method for memory-based QA

- Makes directly reading documents more viable

Question Answering + Knowledge Base

OMDd (+ MovieLens for tags)

Knowledge Base
Jurassic Park *directed_by* Steven Spielberg
Jurassic Park *written_by* David Koepp, Michael Crichton
Jurassic Park *release_year* 1993
Jurassic Park *has_tags* action, adventure, science fiction, …

Question Answering + Knowledge Base

OMDd (+ MovieLens for tags)

Knowledge Base
Jurassic Park *directed_by* Steven Spielberg
Jurassic Park *written_by* David Koepp, Michael Crichton
Jurassic Park *release_year* 1993
Jurassic Park *has_tags* action, adventure, science fiction, …

Who directed Jurassic Park?   Steven Spielberg

Can you describe Jurassic Park in a few words?   A science fiction, action, and adventure movie

In Jurassic Park, what is the name of the island   **???**
where the park is built?

KBs can suffer from missing information and fixed schemas

Question Answering + Open IE

Wikipedia Page: Jurassic Park (film)

Jurassic Park is a 1993 American science fiction action adventure film. The film was directed by Steven Spielberg and is the first installment of the "Jurassic Park" franchise. It is based on the 1990 novel of the same name by Michael Crichton, with a screenplay written by Crichton and David Koepp. The film centers on the fictional Isla Nublar, an islet located off Costa Rica's Pacific Coast, where a billionaire philanthropist and a small team of genetic scientists have created a wildlife park of cloned dinosaurs.

Question Answering + Open IE

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Who directed Jurassic Park?

Can you describe Jurassic Park in a few words?

In Jurassic Park, what is the name of the island where the park is built?

Coreference Resolution
+
Semantic Role Labelling

(or your favorite)

Question Answering + Open IE

Wikipedia Page: Jurassic Park (film)	Open IE Knowledge Base

Jurassic Park is a 1993 American science fiction action adventure film. The film was directed by Steven Spielberg and is the first installment of the "Jurassic Park" franchise. It is based on the 1990 novel of the same name by Michael Crichton, with a screenplay written by Crichton and David Koepp. **The film centers on the fictional Isla Nublar, an islet located off Costa Rica's Pacific Coast, where a billionaire philanthropist and a small team of genetic scientists have created a wildlife park** of cloned dinosaurs.

Jurassic Park *directed by* Steven Spielberg

Jurassic Park *written by* David Koepp and Michael Crichton

Jurassic Park *is a* 1993

Jurassic Park *is a* American science fiction

Jurassic Park *centers on* Isla Nublar

Who directed Jurassic Park?

Can you describe Jurassic Park in a few words?

In Jurassic Park, what is the name of the island where the park is built?

Steven Spielberg

A science fiction, action, and adventure movie

Isla Nublar

Open IE is not an easy problem

Question Answering Directly From Text

Wikipedia Page: Jurassic Park (film)

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Question Answering Directly From Text

Jurassic Park is a 1993 American **science fiction action adventure film**. The film was **directed by Steven Spielberg** and is the first installment of the "Jurassic Park" franchise. It is based on the 1990 novel of the same name by Michael Crichton, with a screenplay written by Crichton and David Koepp. The film centers on the fictional **Isla Nublar**, an islet located off Costa Rica's Pacific Coast, where a billionaire philanthropist and a small team of genetic scientists have created a wildlife park of cloned dinosaurs.

Who directed Jurassic Park?   Steven Spielberg

Can you describe Jurassic Park in a few words?   A science fiction, action, and adventure movie

In Jurassic Park, what is the name of the island where the park is built?   Isla Nublar

Much more information available than in KB

QA is harder but no need for open IE

WikiMovies

Objective:

We want to compare the performance of various learning methods between all three settings (raw, open IE, KB).

A new analysis tool for QA

- A set of 100k question-answer pairs (based on SimpleQuestions)
- 3 Knowledge Sources
  - A KB based on OMBD/MovieLens
  - Raw text extracted from Wikipedia
  - An imperfect KB built with open IE methods
- Answers to all questions appear in both the KB and Wikipedia text

Key-Value Memory Networks

Memory Networks

- Incorporates **reasoning** with **attention** over **memory** (RAM)

- Uses collection of dynamic, addressable slots for storing information

- Learns to read and weight memory slots

- Combines input and memories to choose a response

- Has been successfully applied to QA tasks (among others)

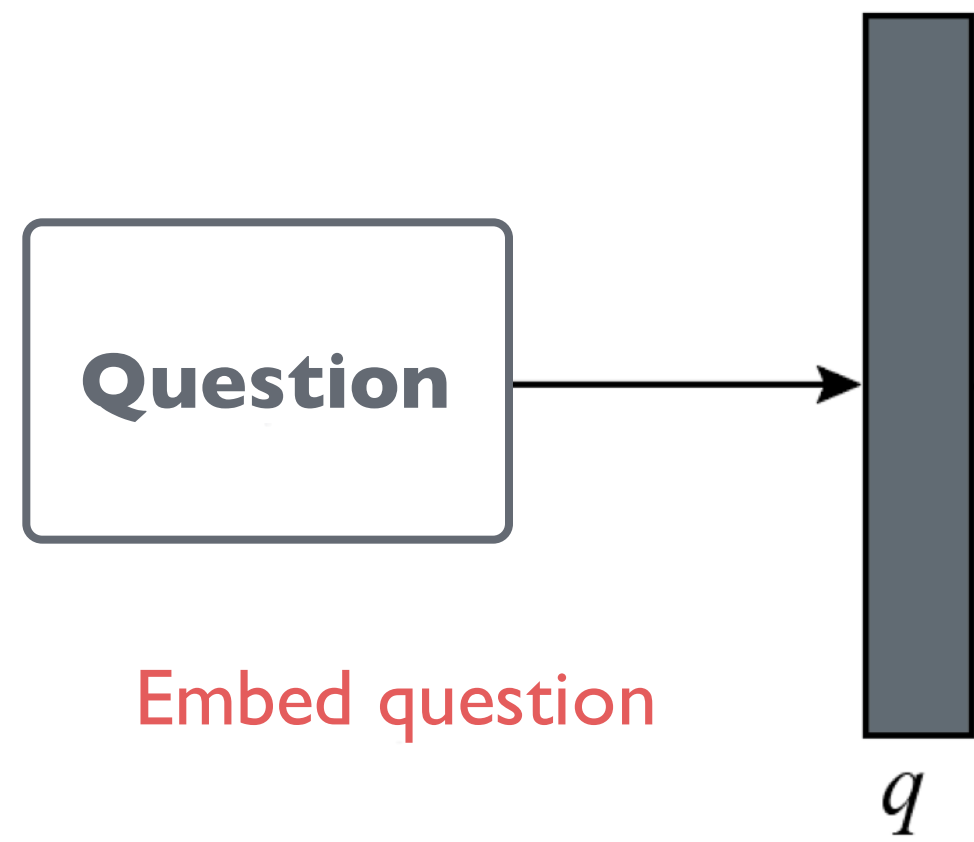 - e.g. bAbi tasks, Children's Book Tasks, etc.

Memory Networks for QA

Question

Memory Networks for QA
(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)
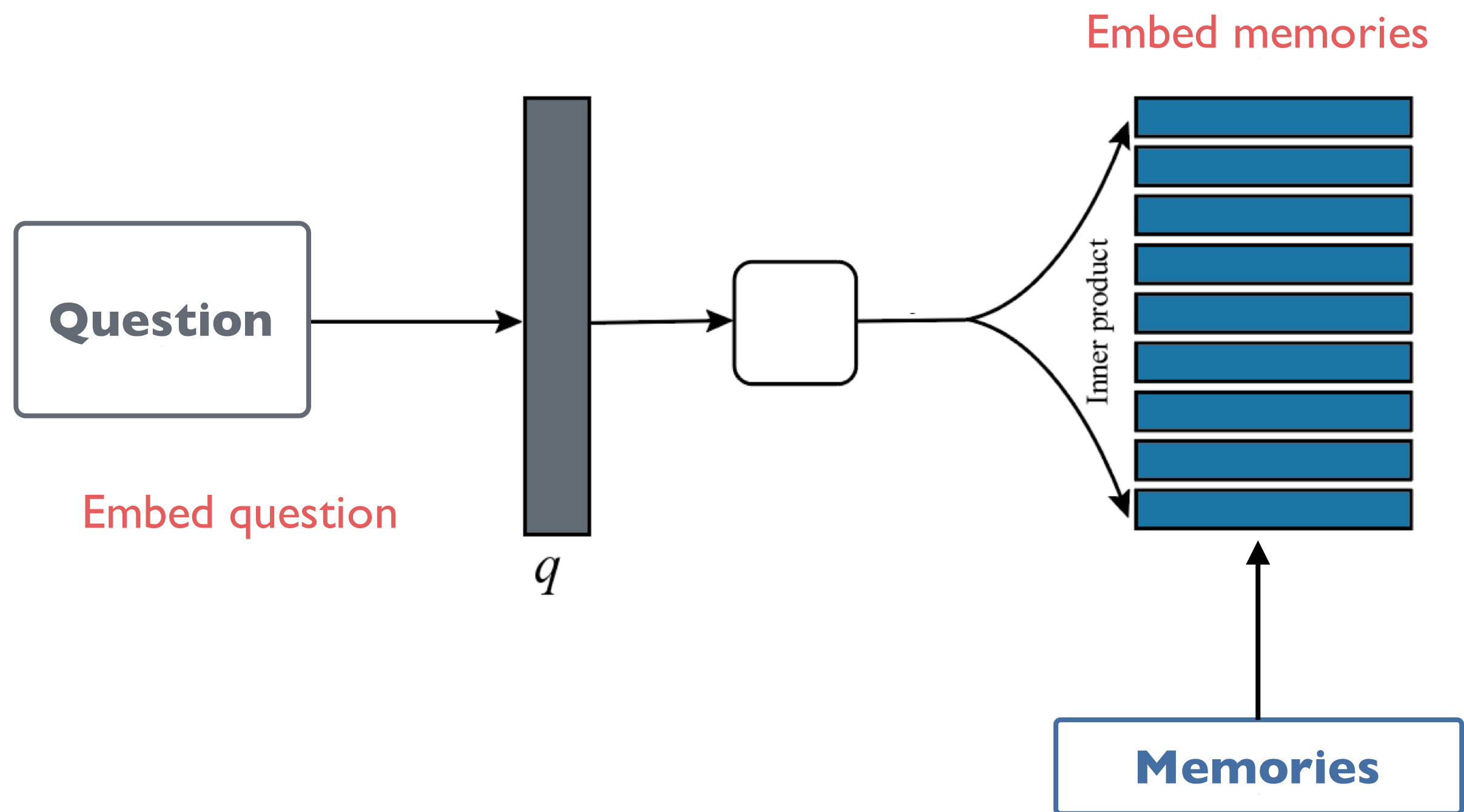

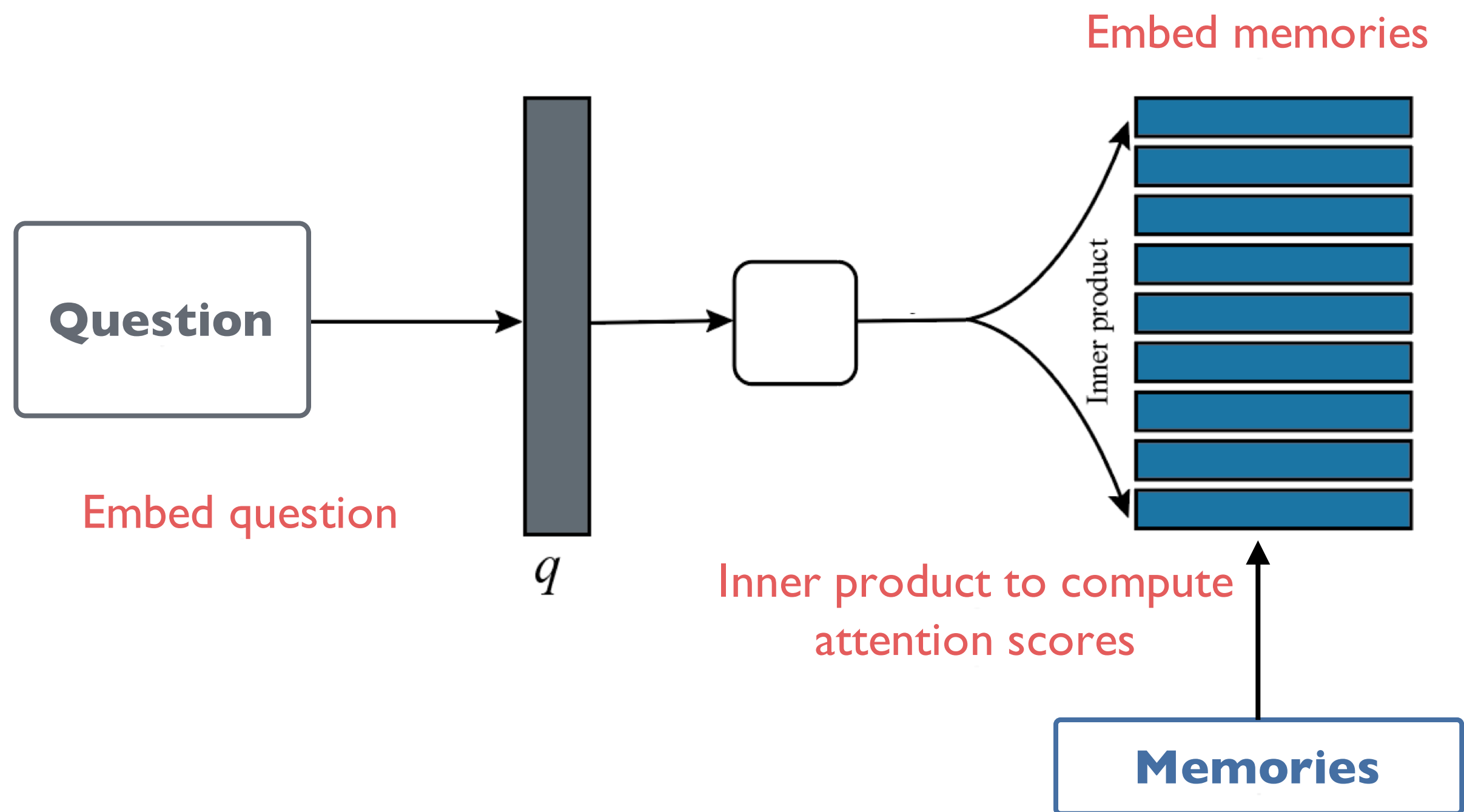Question
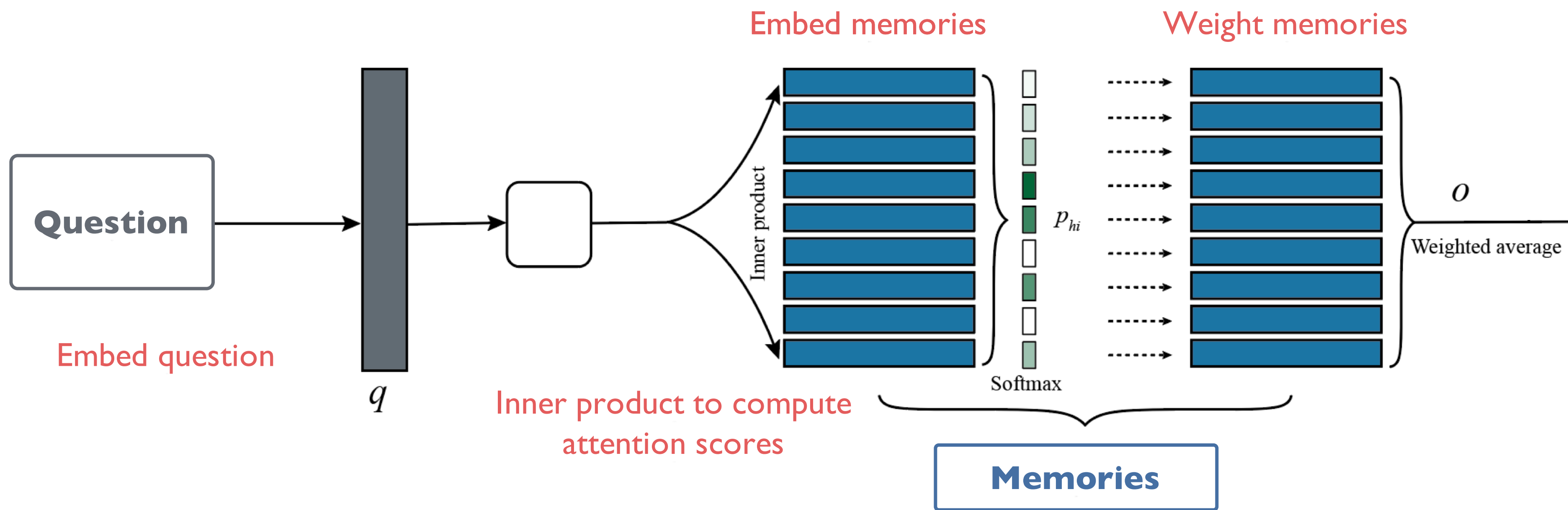
Embed question

q

Memory Networks for QA
(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)

Memory Networks for QA

(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)

Embed memories

Inner product

Question

Embed question

q

Inner product to compute
attention scores

Memories

Memory Networks for QA

(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)

Embed memories   Weight memories

Question

Embed question

q

Inner product to compute attention scores

Inner product

p_{hi}

Softmax

Memories
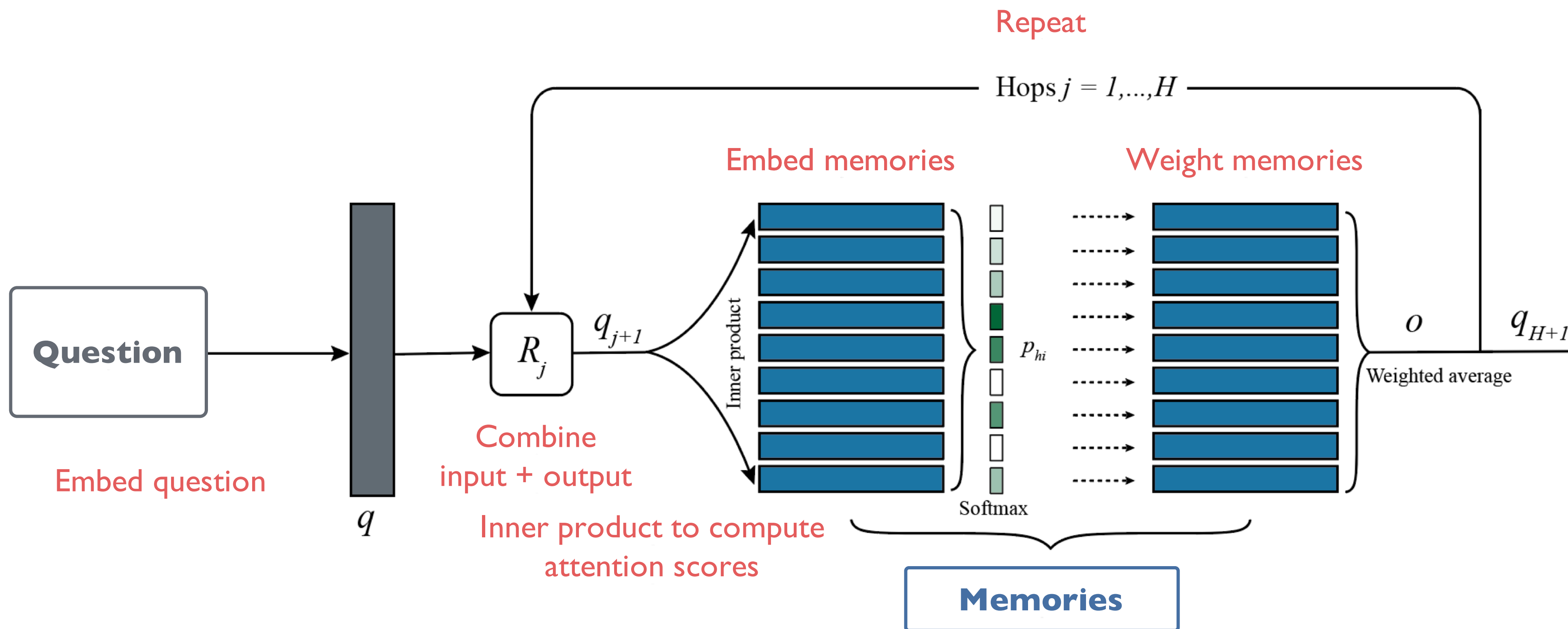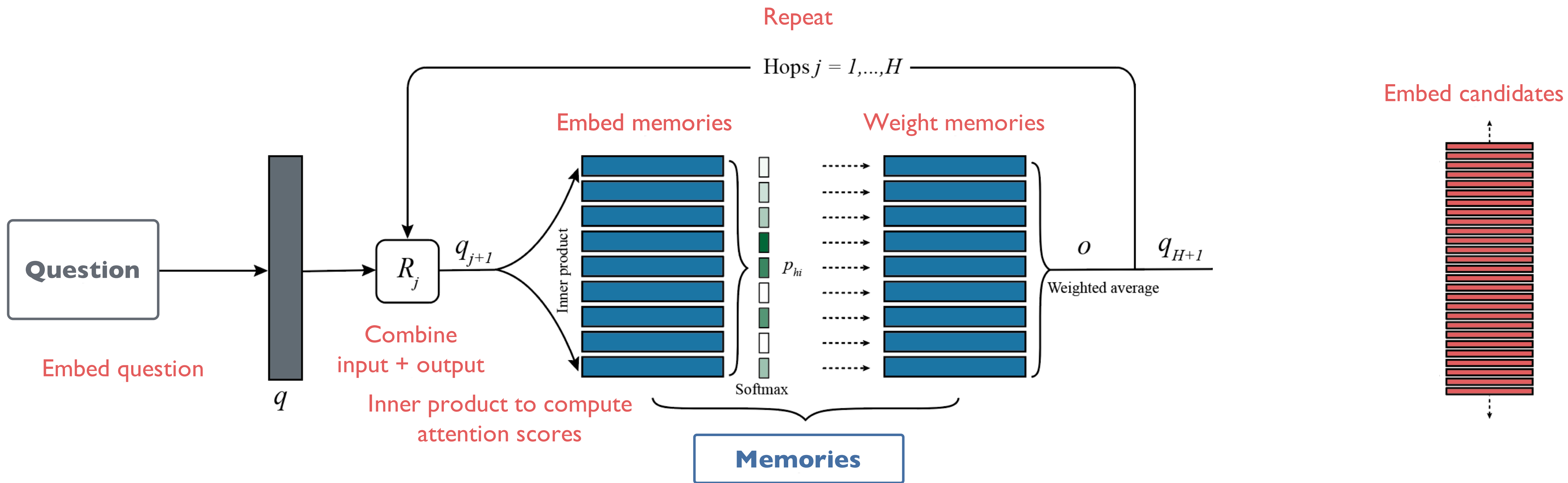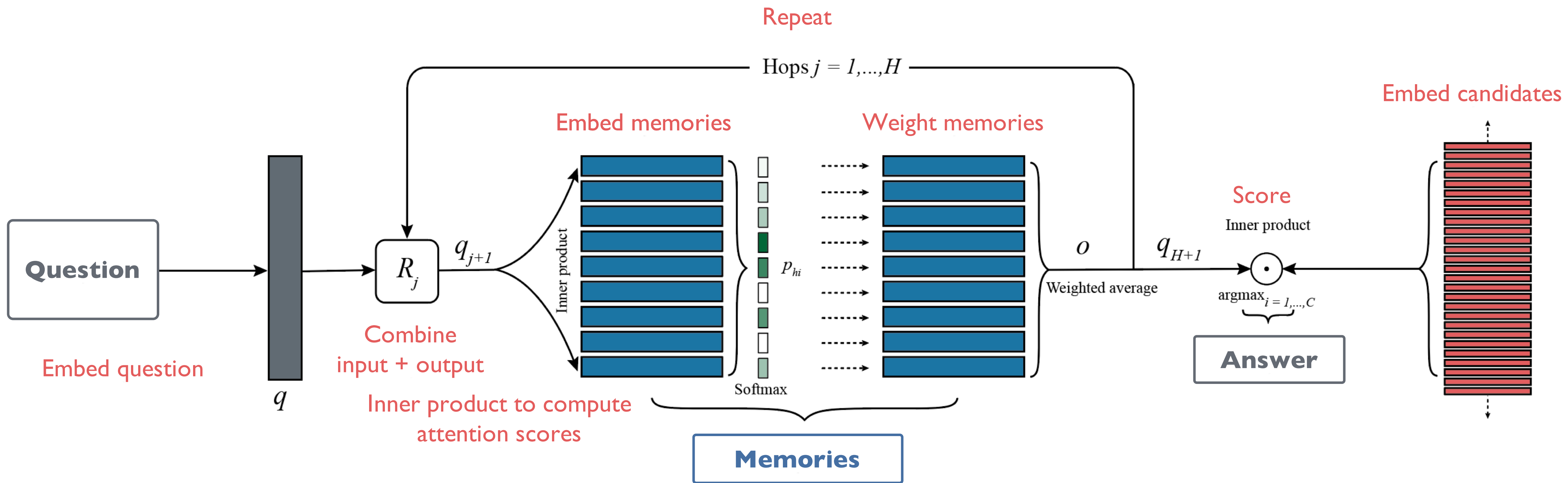
o

Weighted average

Memory Networks for QA
(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)

Memory Networks for QA

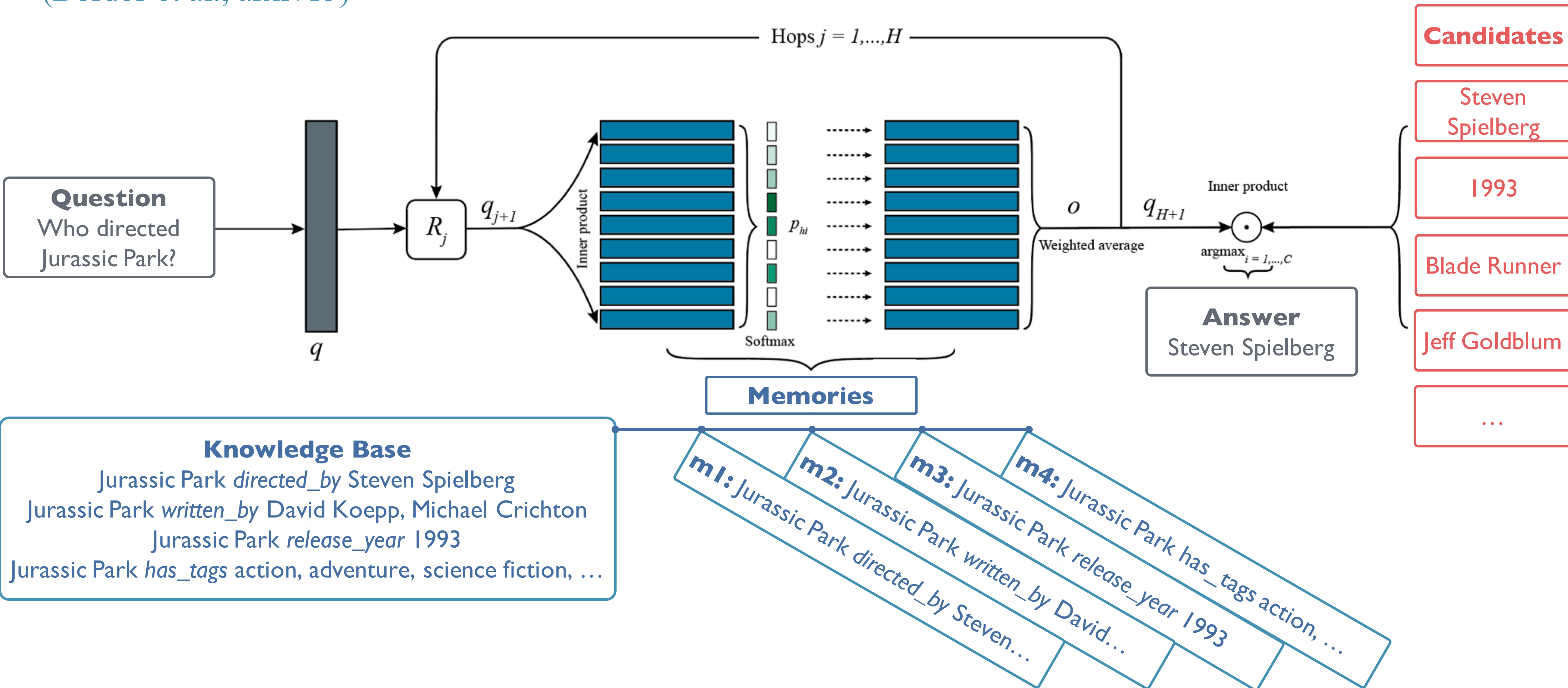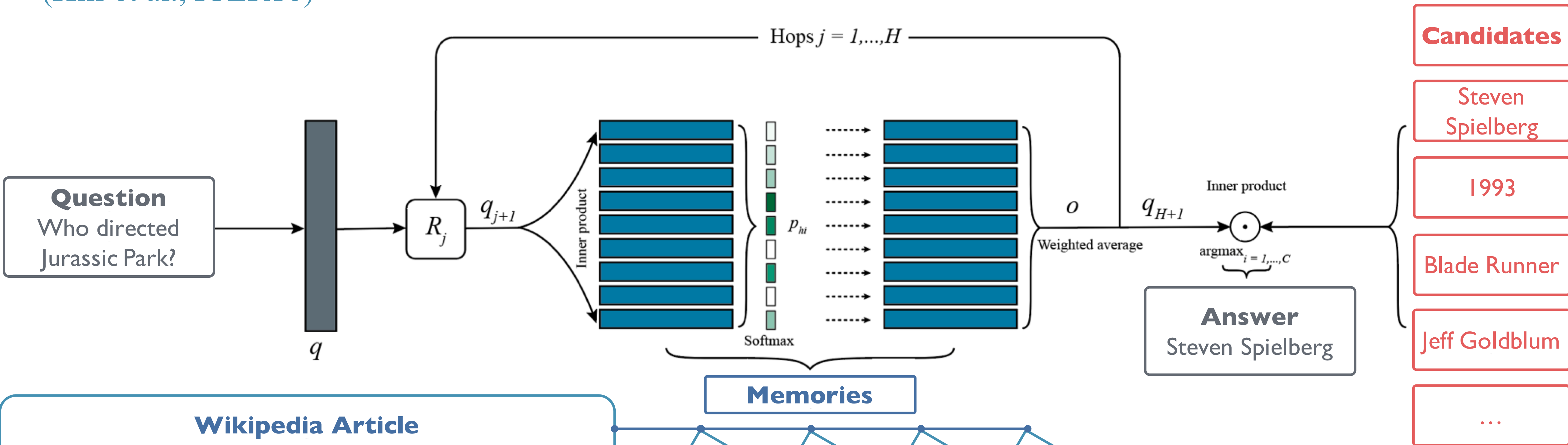(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)

Memory Networks for QA

(Weston et al., ICLR15; Sukhbaatar et al., NIPS15)

Memory Networks for QA from KB

(Bordes et al., arxiv15)

Hops $j = 1,...,H$

Question
Who directed Jurassic Park?

q

R_j

q_{j+1}

Inner product

p_{hi}

Softmax

Memories

o

Weighted average

q_{H+1}

Inner product

argmax$_{i = 1,...,C}$

Answer
Steven Spielberg

Candidates

Steven Spielberg

1993

Blade Runner

Jeff Goldblum

…

Knowledge Base
Jurassic Park *directed_by* Steven Spielberg
Jurassic Park *written_by* David Koepp, Michael Crichton
Jurassic Park *release_year* 1993
Jurassic Park *has_tags* action, adventure, science fiction, …

m1: Jurassic Park directed_by Steven…

m2: Jurassic Park written_by David…

m3: Jurassic Park release_year 1993

m4: Jurassic Park has_tags action, …

Memory Networks for QA from Text
(Hill et al., ICLR16)

Candidates

Steven Spielberg

1993

Blade Runner

Jeff Goldblum

...

Hops $j = 1,...,H$

Question
Who directed Jurassic Park?

q

R_j

q_{j+1}

Inner product

p_{hi}

Softmax

Inner product

o

Weighted average

q_{H+1}

Inner product

$\text{argmax}_{i = 1,...,C}$

Answer
Steven Spielberg

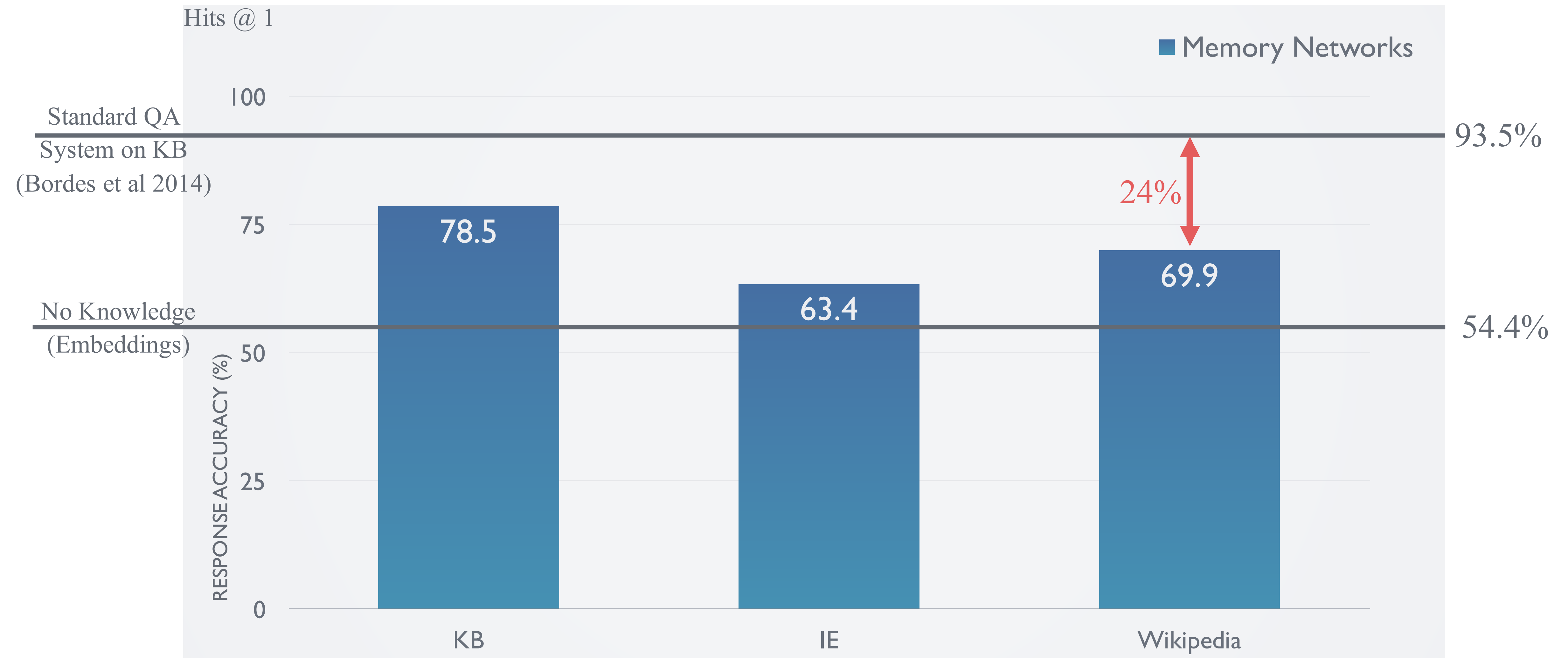**Memories**

Wikipedia Article
Jurassic Park is a 1993 American science fiction action adventure film. The film was directed by Steven Spielberg and is the first installment of the "Jurassic Park" franchise. It is based on the 1990 novel of the same name by Michael Crichton, with a screenplay written by Crichton and David Koepp. The film centers on the fictional Isla Nublar, an islet located off Costa Rica's Pacific Coast, where a billionaire philanthropist and a small team of genetic scientists have created a wildlife park of cloned dinosaurs.

m1: is a 1993 American science

m2: directed by Steven Spielberg and is

m3: on the 1990 novel of

m4: name by Michael Crichton, with

Comparison on WikiMovies

Structuring Memories

Using symbolic structure

Use part of the memory to detect relevance (memory addressing), and the other part for returning a value (memory reading)

Leverage prior knowledge on the task

- One part designed to match the question   ⟵ The key
- One part designed to match the answer   ⟵ The value

Structuring Memories

KB Triple:

Jurassic Park *directed_by* Steven Spielberg

Structuring Memories

KB Triple:

Key	Value
Jurassic Park *directed_by*	**Steven Spielberg**

Structuring Memories

KB Triple:

Key	Value
Jurassic Park *directed_by*	**Steven Spielberg**

Who directed Jurassic Park?

Steven Spielberg

Structuring Memories

Text Window:

directed by Steven Spielberg and is

Structuring Memories

Text Window:

Key	Value
directed by Steven Spielberg and is	**Steven Spielberg**

Structuring Memories

Text Window:

Key	Value
directed by Steven Spielberg and is	**Steven Spielberg**
↑	↑
Who directed Jurassic Park?	Steven Spielberg

Structuring Memories

Text Window: Can we add prior knowledge to help?

Key

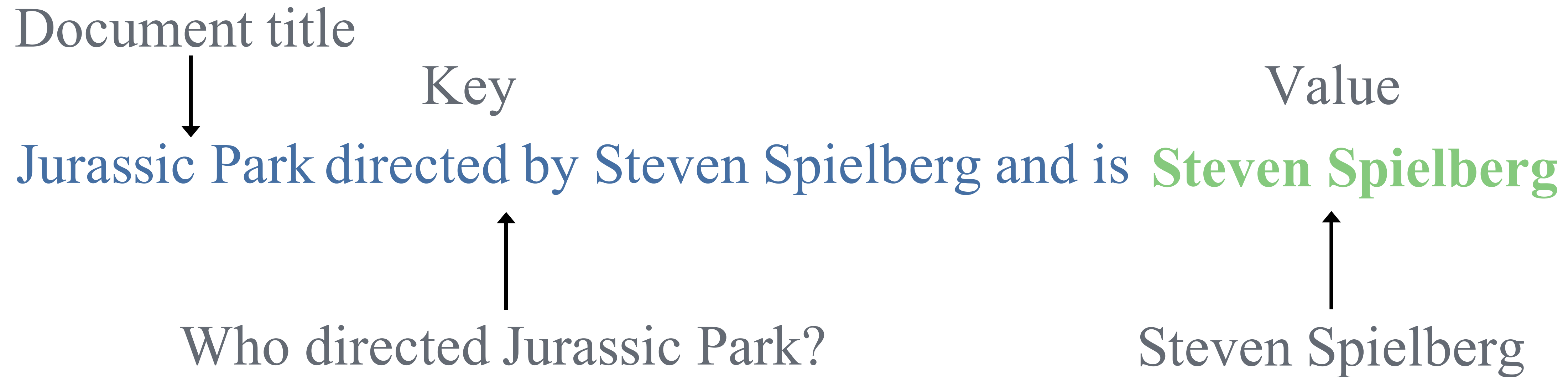directed by Steven Spielberg and is

Who directed Jurassic Park?

Value

Steven Spielberg
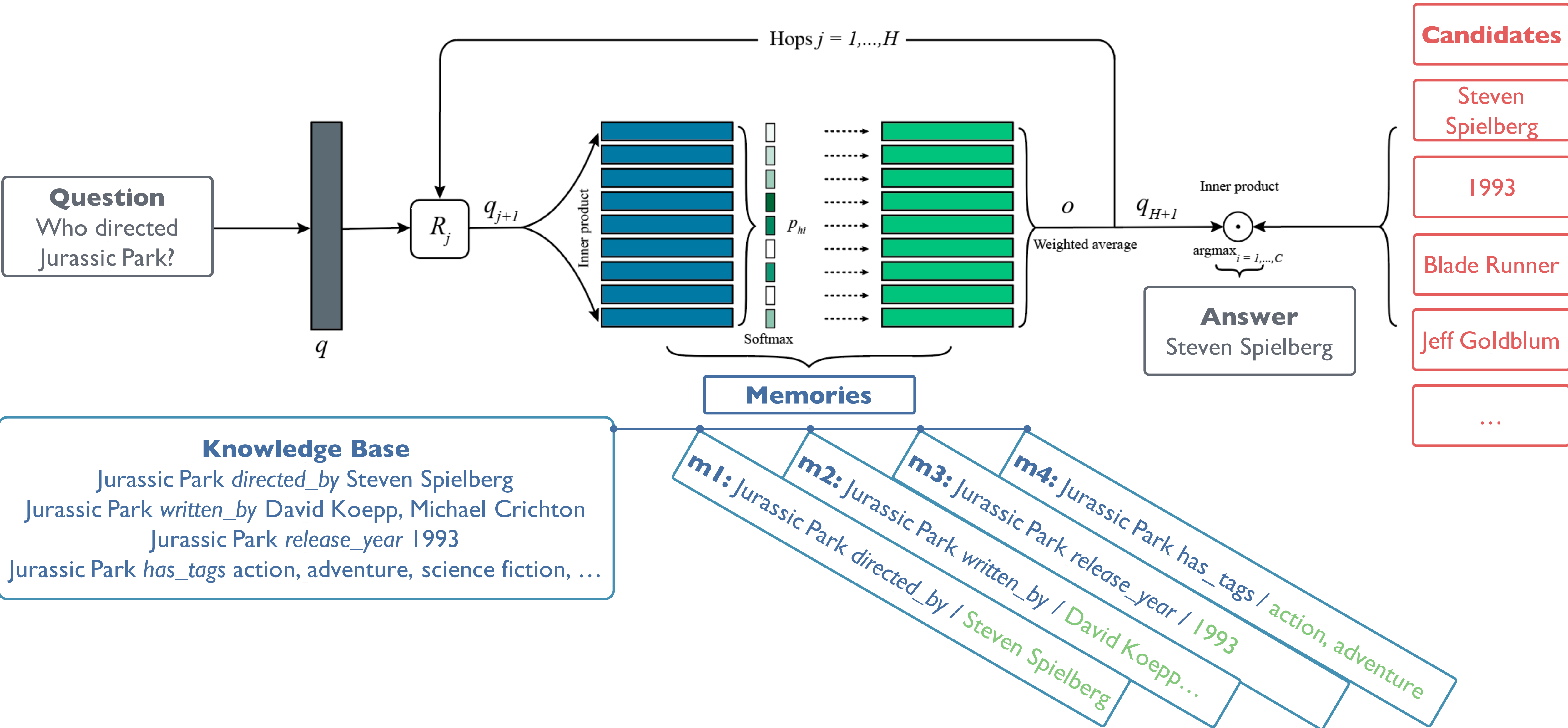
Steven Spielberg

Structuring Memories

Text Window: Can we add prior knowledge to help?

Document title

Key   Value

Jurassic Park directed by Steven Spielberg and is **Steven Spielberg**

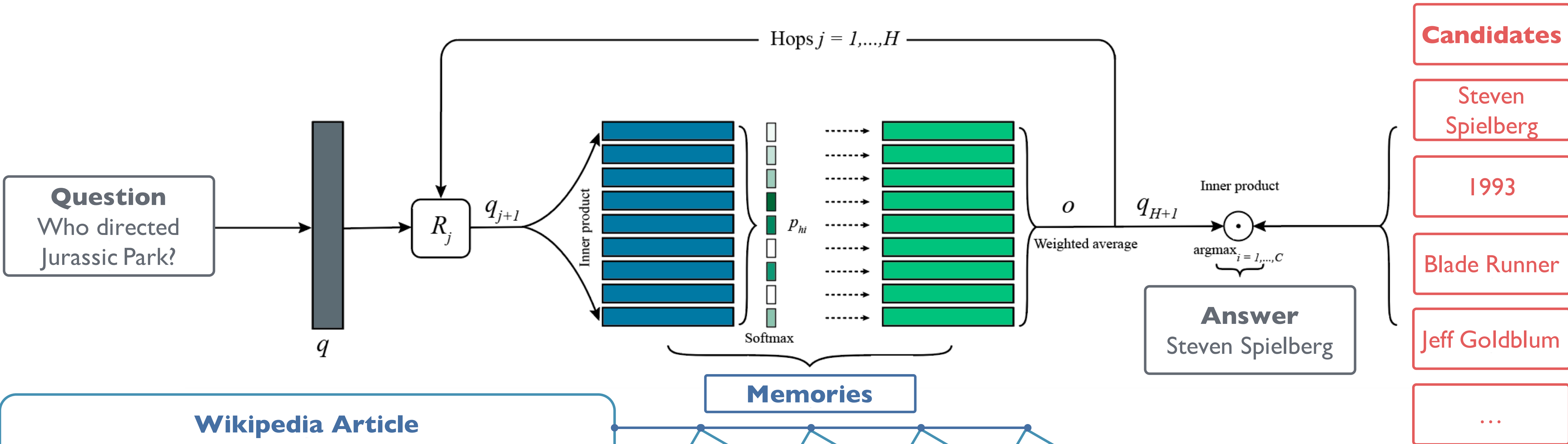Who directed Jurassic Park?   Steven Spielberg

Key-Value Memory Networks

- Generalizes the way context is stored in memory

- Uses a pair of feature extractors — one each for "keys" and "values"

- Memories stored in the form of (*key, value*) pairs

- Provides a simple way to tailor memories

  - Better recall for lookup

  - Better precision for value reading

- Note: Standard Memory Networks are a special case when key = value

Key-Value Memory Networks from KB
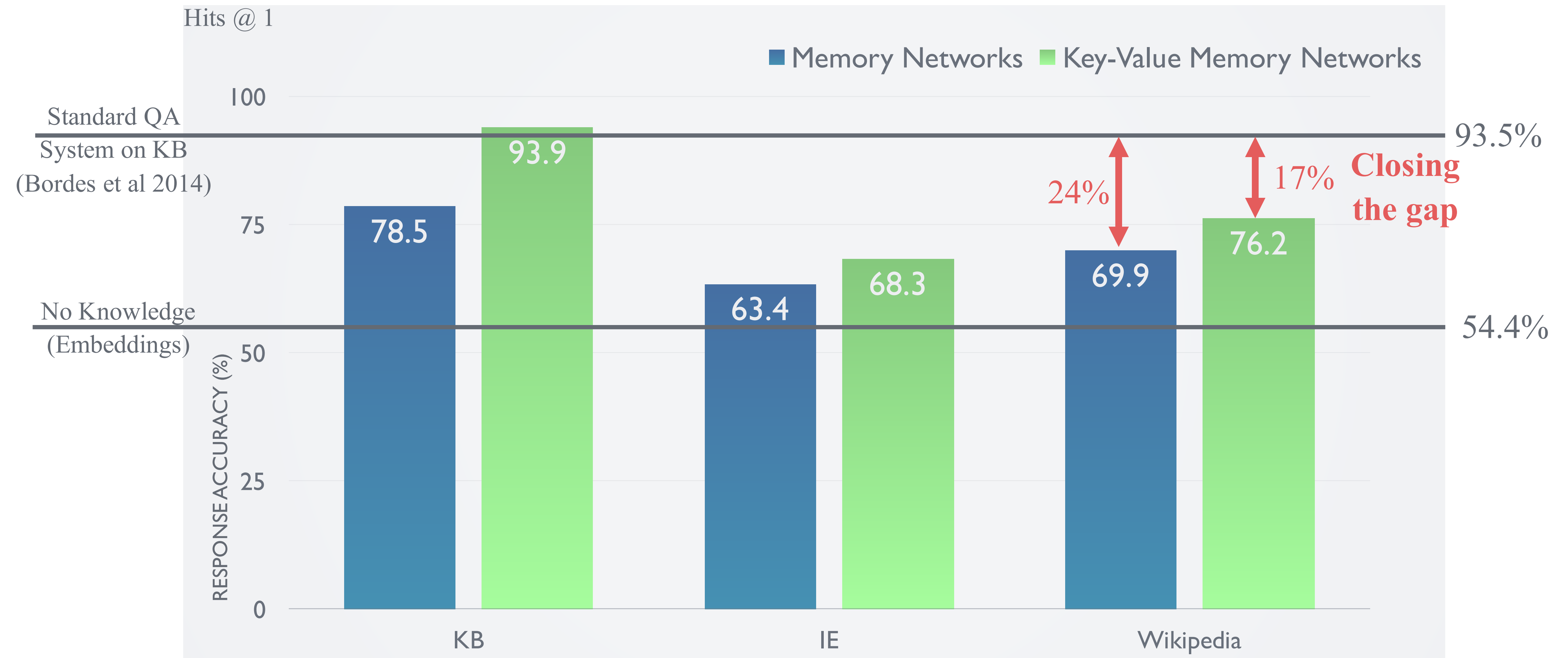
Key-Value Memory Networks from Text

Comparison on WikiMovies

Hits @ 1

Memory Networks ■ Key-Value Memory Networks ■

Standard QA
System on KB
(Bordes et al 2014)

No Knowledge
(Embeddings)

93.5%

54.4%

**Closing
the gap**

24%   17%

	KB		IE		Wikipedia	
Memory Networks	78.5		63.4		69.9	
Key-Value Memory Networks		93.9		68.3		76.2

RESPONSE ACCURACY (%)

100
75
50
25
0

WikiQA

QA Benchmark in the answer selection setting

- Given question + set of sentences (paragraph), select which sentence contains the answer
- Key-value Memories: (window, sentence)

A glacier cave is a / **A glacier cave is a cave formed within the ice of a glacier**	
a cave formed within the / **A glacier cave is a cave formed within the ice of a glacier**	
the ice of a glacier / **A glacier cave is a cave formed within the ice of a glacier**	

WikiQA

QA Benchmark in the answer selection setting

- Given question + set of sentences (paragraph), select which sentence contains the answer

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A glacier cave is a / **A glacier cave is a cave formed within the ice of a glacier**

---

a cave formed within the / **A glacier cave is a cave formed within the ice of a glacier**

---

the ice of a glacier / **A glacier cave is a cave formed within the ice of a glacier**

- Training size is very small (~1k examples)
  - Word embeddings pre-trained on Wikipedia then fixed
  - Input, memory, and label dropout regularization

WikiQA

Method	MAP	MRR
Word Cnt	0.4891	0.4924
Wgt Word Cnt	0.5099	0.5132
2-gramm CNN (Yang *et al.*, 2015)	0.6520	0.6652
AP-CNN (Santos *et al.*, 2016)	0.6886	0.7069
Attentive LSTM (Miao *et al.*, 2015)	0.6886	0.7069
Attentive CNN (Yin and Schütze, 2015)	0.6921	0.7108
L.D.C. (Wang *et al.*, 2016)	**0.7058**	**0.7226**
Memory Network	0.5170	0.5236
Key-Value Memory Network	**0.7069**	**0.7265**

Conclusion

Key-Value Memory Networks

Promising model for jointly using symbolic and continuous memory

- Can be trained end-to-end using backpropagation + SGD
- Introduces great flexibility in how memories are designed
- Future work: selecting key and value content, applying to other domains

WikiMovies (https://research.facebook.com/research/babi/)

- New tool for evaluating and comparing learning algorithms
- Training / Evaluation sets of reasonable size
- Future work: close gap between KB and raw text

facebook