

Natural Language Processing

Info 159/259

Lecture 18: Question Answering (April 3, 2024)

*Many slides & instruction ideas borrowed from:
David Bamman & Greg Durrett*

Relation extraction

The Big Sleep is a 1946 film noir directed by Howard Hawks,^{[2][3]} the first film version of Raymond Chandler's 1939 novel of the same name. The film stars Humphrey Bogart as private detective Philip Marlowe and Lauren Bacall as Vivian Rutledge in a story about the "process of a criminal investigation, not its results."^[4] William Faulkner, Leigh Brackett and Jules Furthman co-wrote the screenplay.

<i>subject</i>	<i>predicate</i>	<i>object</i>
The Big Sleep	directed_by	Howard Hawks
The Big Sleep	stars	Humphrey Bogart
The Big Sleep	stars	Lauren Bacall
The Big Sleep	screenplay_by	William Faulkner
The Big Sleep	screenplay_by	Leigh Brackett
The Big Sleep	screenplay_by	Jules Furthman

Relation extraction

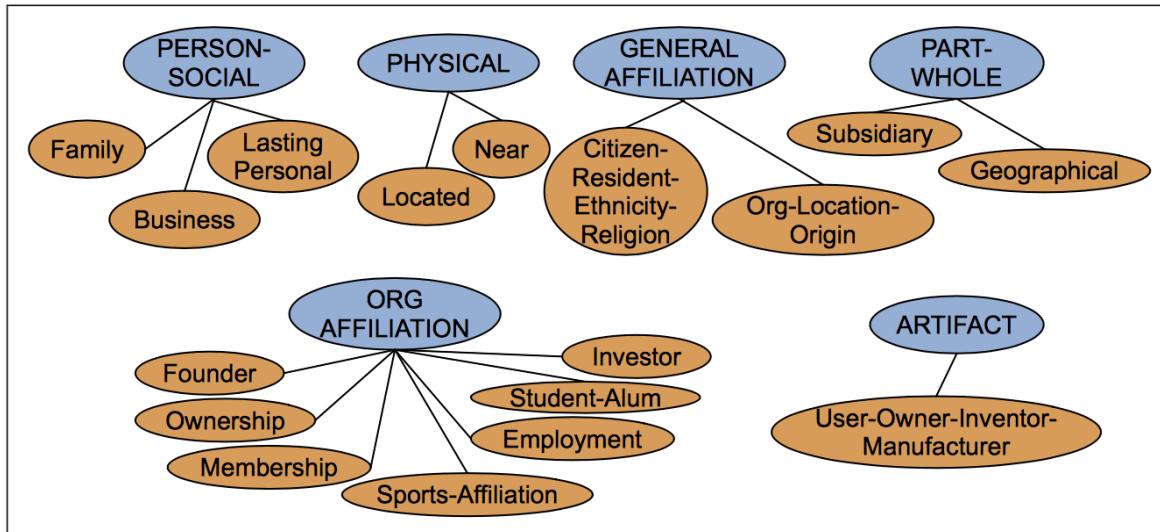


Figure 17.9 The 17 relations used in the ACE relation extraction task.

Wikipedia Infoboxes

The Big Sleep is a 1946 film noir directed by Howard Hawks,^{[2][3]} the first film version of Raymond Chandler's 1939 novel of the same name. The film stars Humphrey Bogart as private detective Philip Marlowe and Lauren Bacall as Vivian Rutledge in a story about the "process of a criminal investigation, not its results."^[4] William Faulkner, Leigh Brackett and Jules Furthman co-wrote the screenplay.

A remake starring Robert Mitchum as Philip Marlowe was released in 1978. This was the second film in three years featuring Mitchum as Marlowe. The remake was arguably more faithful to the novel, possibly due to fewer restrictions in 1978 on what could be portrayed on screen, however, it was far less successful than the original 1946 version. In 1997, the U.S. Library of Congress deemed the film "culturally, historically, or aesthetically significant," and added it to the National Film Registry.

<i>The Big Sleep</i>	
	Theatrical release lobby card
<hr/>	
Directed by	Howard Hawks
Produced by	Howard Hawks
Screenplay by	William Faulkner Leigh Brackett Jules Furthman
Based on	<i>The Big Sleep</i> by Raymond Chandler
Starring	Humphrey Bogart Lauren Bacall
Music by	Max Steiner
Cinematography	Sidney Hickox
Edited by	Christian Nyby
Distributed by	Warner Bros.
Release date	August 23, 1946 (United States)
Running time	114 minutes (released cut) 116 minutes (re-released original cut)

Hearst patterns

<i>pattern</i>	<i>sentence</i>
NP {, NP}* {,} (and or) other NP _H	temples, treasures, and other important civic buildings
NP _H such as {NP,}* {(or and)} NP	red algae such as Gelidium
such NP _H as {NP,}* {(or and)} NP	such authors as Herrick, Goldsmith, and Shakespeare
NP _H {,} including {NP,}* {(or and)} NP	common-law countries, including Canada and England
NP _H {,} especially {NP,}* {(or and)} NP	European countries, especially France, England, and Spain

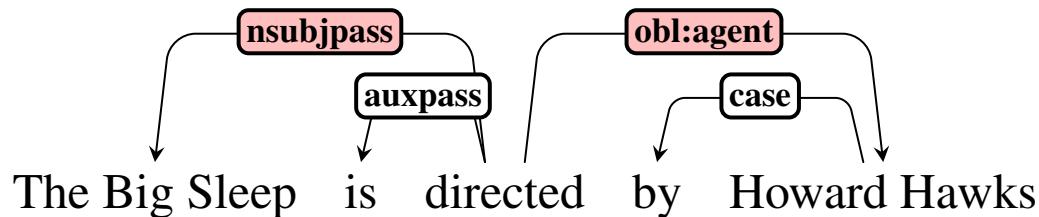
Supervised relation extraction

[The Big Sleep]_{m1} is a 1946 film noir directed by [Howard Hawks]_{m2}, the first film version of Raymond Chandler's 1939 novel of the same name.

feature(m1, m2)
headwords of m1, m2
bag of words in m1, m2
bag of words between m1, m2
named entity types of m1, m2
syntactic path between m1, m2

Supervised relation extraction

[The Big Sleep]_{m1} is a 1946 film noir directed by [Howard Hawks]_{m2}, the first film version of Raymond Chandler's 1939 novel of the same name.



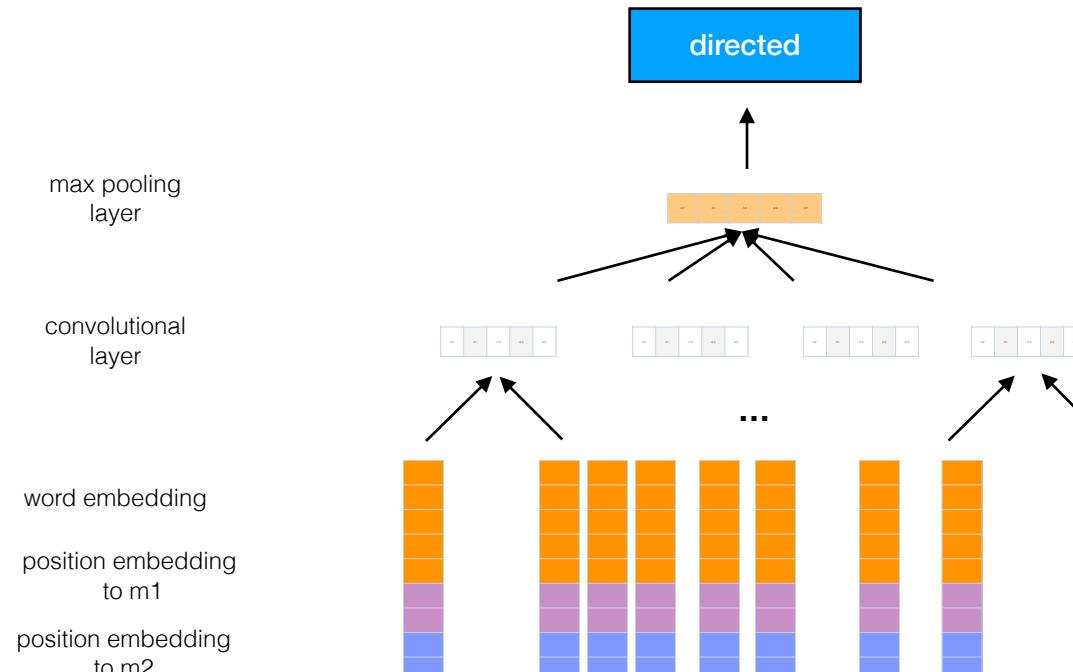
[The Big Sleep]_{m1} ← *nsubjpass* directed → *obl:agent* [Howard Hawks]_{m2},

$m1 \xleftarrow{nsubjpass} \xleftarrow{\text{directed}} m2 \xrightarrow{\text{obl:agent}}$

Supervised relation extraction

```
function FINDRELATIONS(words) returns relations
    relations  $\leftarrow$  nil
    entities  $\leftarrow$  FINDENTITIES(words)
    forall entity pairs  $\langle e_1, e_2 \rangle$  in entities do
        if RELATED?(e1, e2)
            relations  $\leftarrow$  relations + CLASSIFYRELATION(e1, e2)
```

Figure 17.13 Finding and classifying the relations among entities in a text.



[The Big Sleep] _{m_1} is a 1946 film noir directed by [Howard Hawks] _{m_2}

Distant supervision

- It's uncommon to have labeled data in the form of <sentence, relation> pairs

<i>sentence</i>	<i>relations</i>
[The Big Sleep] _{m1} is a 1946 film noir directed by [Howard Hawks] _{m2} , the first film version of Raymond Chandler's 1939 novel of the same name.	directed_by(The Big Sleep, Howard Hawks)

Distant supervision

- More common to have knowledge base data about entities and their relations that's separate from text.
- We know the text likely expresses the relations somewhere, but not **exactly where**.

Wikipedia Infoboxes

The Big Sleep is a 1946 film noir directed by Howard Hawks,^{[2][3]} the first film version of Raymond Chandler's 1939 novel of the same name. The film stars Humphrey Bogart as private detective Philip Marlowe and Lauren Bacall as Vivian Rutledge in a story about the "process of a criminal investigation, not its results."^[4] William Faulkner, Leigh Brackett and Jules Furthman co-wrote the screenplay.

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Relation name	Size	Example
/people/person/nationality	281,107	John Dugard, South Africa
/location/location/contains	253,223	Belgium, Nijlen
/people/person/profession	208,888	Dusa McDuff, Mathematician
/people/person/place_of_birth	105,799	Edwin Hubble, Marshfield
/dining/restaurant/cuisine	86,213	MacAyo's Mexican Kitchen, Mexican
/business/business_chain/location	66,529	Apple Inc., Apple Inc., South Park, NC
/biology/organism_classification_rank	42,806	Scorpaeniformes, Order
/film/film/genre	40,658	Where the Sidewalk Ends, Film noir
/film/film/language	31,103	Enter the Phoenix, Cantonese
/biology/organism_higher_classification	30,052	Calopteryx, Calopterygidae
/film/film/country	27,217	Turtle Diary, United States
/film/writer/film	23,856	Irving Shulman, Rebel Without a Cause
/film/director/film	23,539	Michael Mann, Collateral
/film/producer/film	22,079	Diane Eskenazi, Aladdin
/people/deceased_person/place_of_death	18,814	John W. Kern, Asheville
/music/artist/origin	18,619	The Octopus Project, Austin
/people/person/religion	17,582	Joseph Chartrand, Catholicism
/book/author/works_written	17,278	Paul Auster, Travels in the Scriptorium
/soccer/football_position/players	17,244	Midfielder, Chen Tao
/people/deceased_person/cause_of_death	16,709	Richard Daintree, Tuberculosis
/book/book/genre	16,431	Pony Soldiers, Science fiction
/film/film/music	14,070	Stavisky, Stephen Sondheim
/business/company/industry	13,805	ATS Medical, Health care

Table 2: The 23 largest Freebase relations we use, with their size and an instance of each relation.

Distant supervision

mayor(Maynard Jackson, Atlanta)

Elected mayor of Atlanta in 1973, Maynard Jackson...

Atlanta's airport will be renamed to honor Maynard Jackson, the city's first Black mayor

Born in Dallas, Texas in 1938, Maynard Holbrook Jackson, Jr. moved to Atlanta when he was 8.

mayor(Fiorello LaGuardia, New York)

Fiorello LaGuardia was Mayor of New York for three terms...

Fiorello LaGuardia, then serving on the New York City Board of Aldermen...

Distant supervision

- For feature-based models, we can represent the tuple $\langle m_1, m_2 \rangle$ by aggregating together the representations from all the sentences they appear in

Distant supervision

[The Big Sleep]_{m1} is a 1946 film noir directed by [Howard Hawks]_{m2}, the first film version of Raymond Chandler's 1939 novel of the same name.

[Howard Hawks]_{m2} directed the [The Big Sleep]_{m1}

feature(m1, m2)	value (e.g., normalized over all sentences)
“directed” between m1, m2	0.37
“by” between m1, m2	0.42
$m1 \leftarrow nsubj \leftarrow \text{directed} \rightarrow obl:agent \rightarrow m2$	0.13
$m2 \leftarrow nsubj \leftarrow \text{directed} \rightarrow obj \rightarrow m2$	0.08

Distant supervision

- Discovering Hearst patterns from distant supervision using WordNet (Snow et al. 2005)

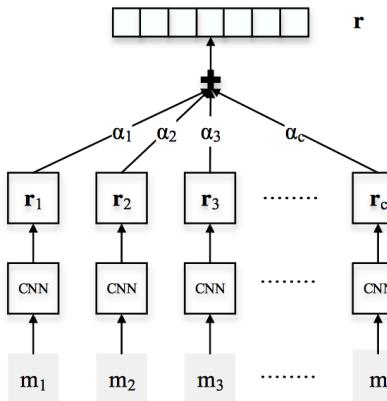
<i>pattern</i>	<i>sentence</i>
NP_H like NP	Many hormones like leptin...
NP_H called NP	a markup language called XHTML
NP is a NP_H	Ruby is a programming language...
NP, a NP_H	IBM, a company with a long...

Multiple Instance Learning

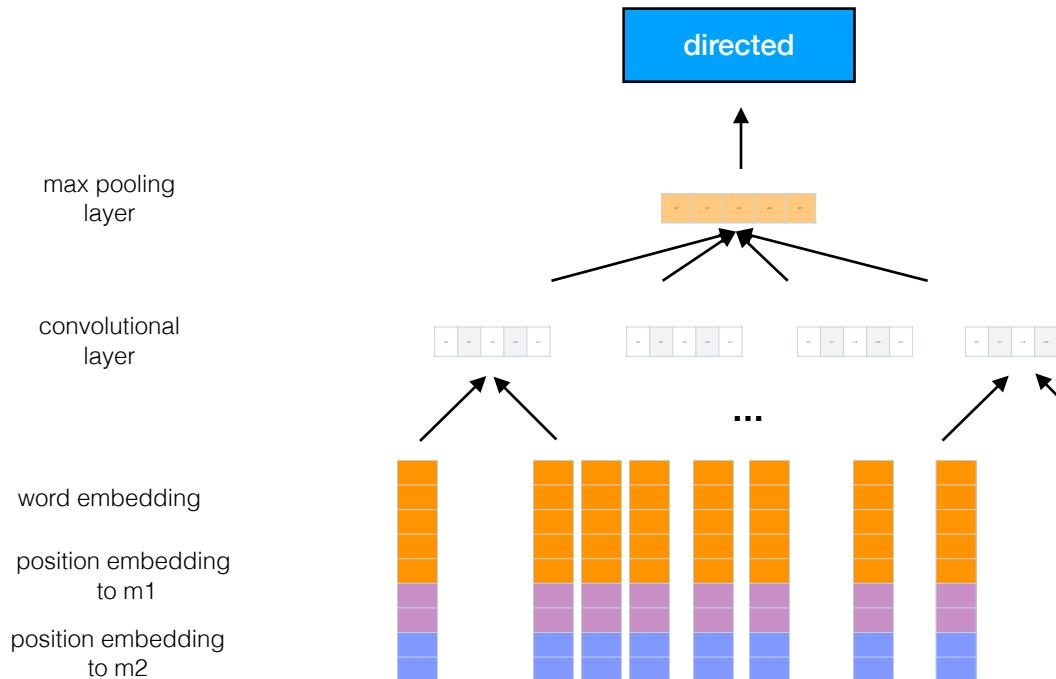
- Labels are assigned to a set of sentences, each containing the pair of entities m_1 and m_2 ; not all of those sentences express the relation between m_1 and m_2 .

Attention

- Let's incorporate structure (and parameters) into a network that captures which **sentences** in the input we should be **attending** to (and which we can ignore).

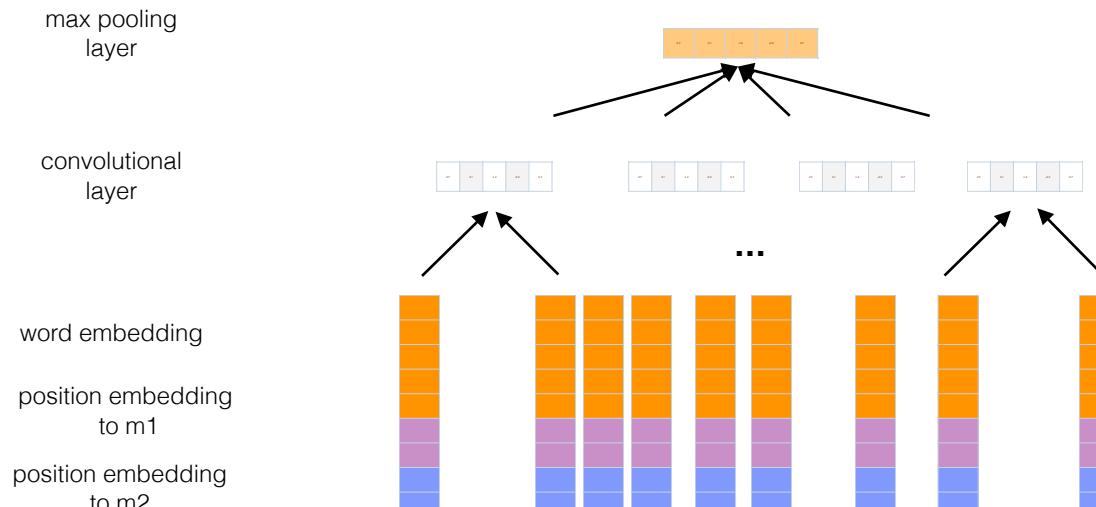


Lin et al (2016), “Neural Relation Extraction with Selective Attention over Instances” (ACL)

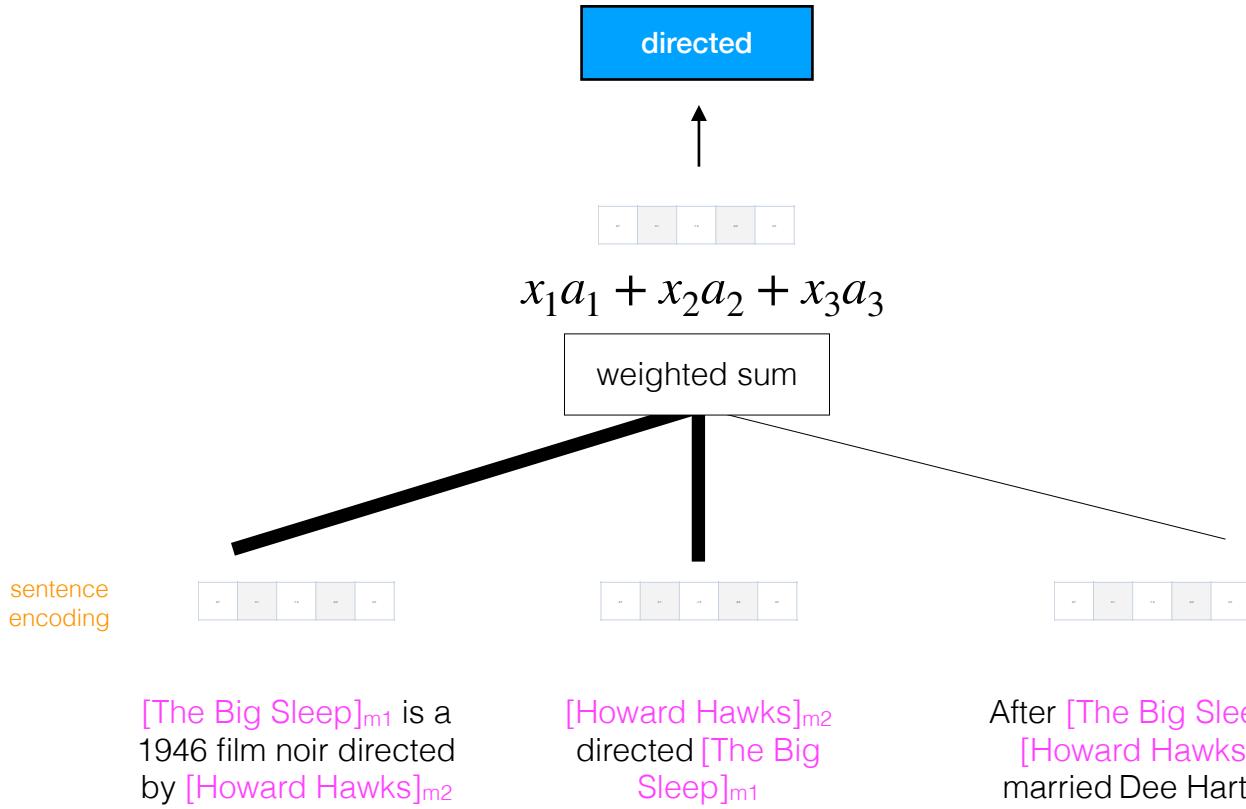


$[The\ Big\ Sleep]_{m1}$ is a 1946 film noir directed by $[Howard\ Hawks]_{m2}$

Now we just have an encoding
of a sentence



[The Big Sleep]_{m1} is a 1946 film noir directed by [Howard Hawks]_{m2}



Information Extraction

- Named entity recognition
- Entity linking
- Relation extraction
- Template filling
- Event detection
- Event coreference
- ...

Question Answering

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<https://www.house.gov> ::

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Speaker Nancy Pelosi addresses the Members of the 116th **Congress**. ... The Office of the Clerk gives you a front-row seat. U.S. Capitol dome at night. Find Your ...

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[How many US Congress are there?](#) ▾

[What are the two houses of the US Congress?](#) ▾

[Which party is Congress in USA?](#) ▾

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United States Congress



congress.gov

The United States Congress or U.S. Congress is the bicameral legislature of the federal government of the United States and consists of the House of Representatives and the Senate. The Congress meets in the United States Capitol in Washington, D.C. [Wikipedia](#)

Founded: March 4, 1789

Headquarters: [Washington, D.C.](#)

Senate last election: November 3, 2020

Senate next election: November 8, 2022

President of the Senate: [Kamala Harris \(D\)](#); since January 20, 2021

Senate president pro tempore: [Patrick Leahy \(D\)](#); since January 20, 2021



which film got the best picture award at the oscars 2024



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About 244,000,000 results (0.50 seconds)

Oppenheimer

'Oppenheimer' was named best picture, while Christopher Nolan, Emma Stone, Cillian Murphy, Robert Downey Jr., Da'Vine Joy Randolph and Billie Eilish & Finneas O'Connell are among those taking home the gold.

Mar 10, 2024



The Hollywood Reporter

<https://www.hollywoodreporter.com> › movie-news › osc...



[Oscar 2024 Winners: The Full List - The Hollywood Reporter](#)



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What movie won best picture 2024?



96th Academy Awards

March 10, 2024 at 4:00 PM PDT :



Winners

Cillian Murphy

Best Actor · Oppenheimer



Emma Stone

Best Actress · Poor Things



Oppenheimer

Best Picture · Christopher Nolan, Emma T...



The Zone of Interest

Best International Feature Film · Jonathan...

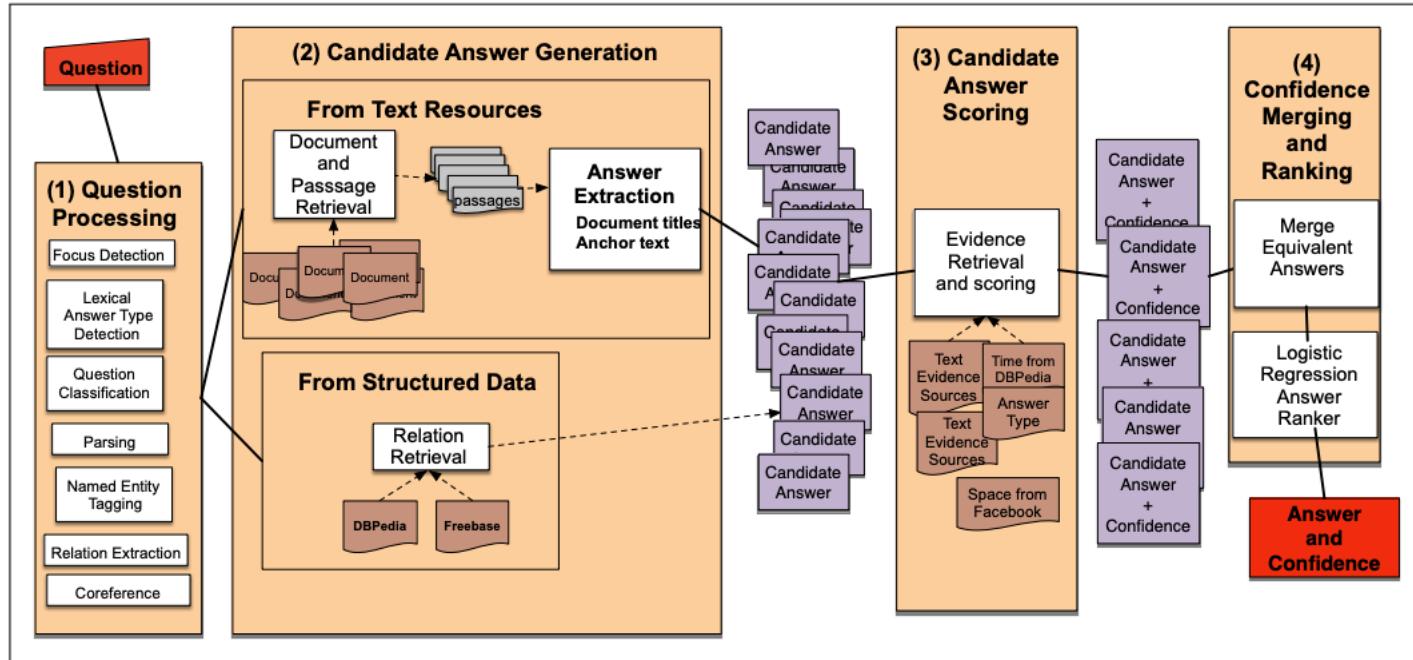


[See full list](#)

Watson



Classic QA: Watson



 You

which building is the oldest in UC-Berkeley



ChatGPT

The oldest building on the University of California, Berkeley campus is South Hall. Constructed in 1873, South Hall is a historic landmark and one of the original buildings of the university. It served as the university's main administrative and academic building in its early years. Today, South Hall continues to be used for academic purposes and is recognized as an important symbol of UC Berkeley's history and heritage.

 You

How many story does that have



ChatGPT

South Hall at UC Berkeley is a four-story building.



Factoid questions

- Questions that can be answered with simple facts:
 - Who founded Virgin Airlines?
 - What is the average age of the onset of autism?
 - Where is Apple Computer based?
 - ~~How do I get to be a cook at the French Laundry?~~

Question Answering Solutions

- Knowledge-based question answering
- IR-based question answering
- LLM-based question answering

Knowledge-based QA

- Parse a question into a meaning representation, and execute that meaning representation against a database.

SQL	What record company did conductor Mikhail Snitko record for after 1996? SELECT RecordCompany WHERE (YearOfRecording > 1996) AND (Conductor = Mikhail Snitko)
-----	---

Semantics

Lexical semantics is concerned with representing the meaning of words (and their relations)

Logical semantics is concerned with representing the meaning of sentences.

Meaning representation

- A representation of the meaning of a sentence needs to bridge **linguistic** aspects of the sentence with **non-linguistic** knowledge about the world.

Meaning representation

Geo	which state has the most rivers running through it? $(\text{argmax } \$0 \ (\text{state}:t \ \$0) \ (\text{count } \$1 \ (\text{and} \ (\text{river}:t \ \$1) \ (\text{loc}:t \ \$1 \ \$0))))$
ATIS	all flights from dallas before 10am $(\lambda \$0 \ e \ (\text{and} \ (\text{flight } \$0) \ (\text{from } \$0 \ \text{dallas:ci}) \ (< \ (\text{departure time } \$0) \ 1000:t)))$
SQL	What record company did conductor Mikhail Snitko record for after 1996? <code>SELECT Record Company WHERE (Year of Recording > 1996) AND (Conductor = Mikhail Snitko)</code>
Django	if length of bits is lesser than integer 3 or second element of bits is not equal to string 'as' <code>if len(bits) < 3 or bits[1] != 'as':</code>

KR-based QA

- Challenge of scaling to all kinds of relations.

IR-based QA

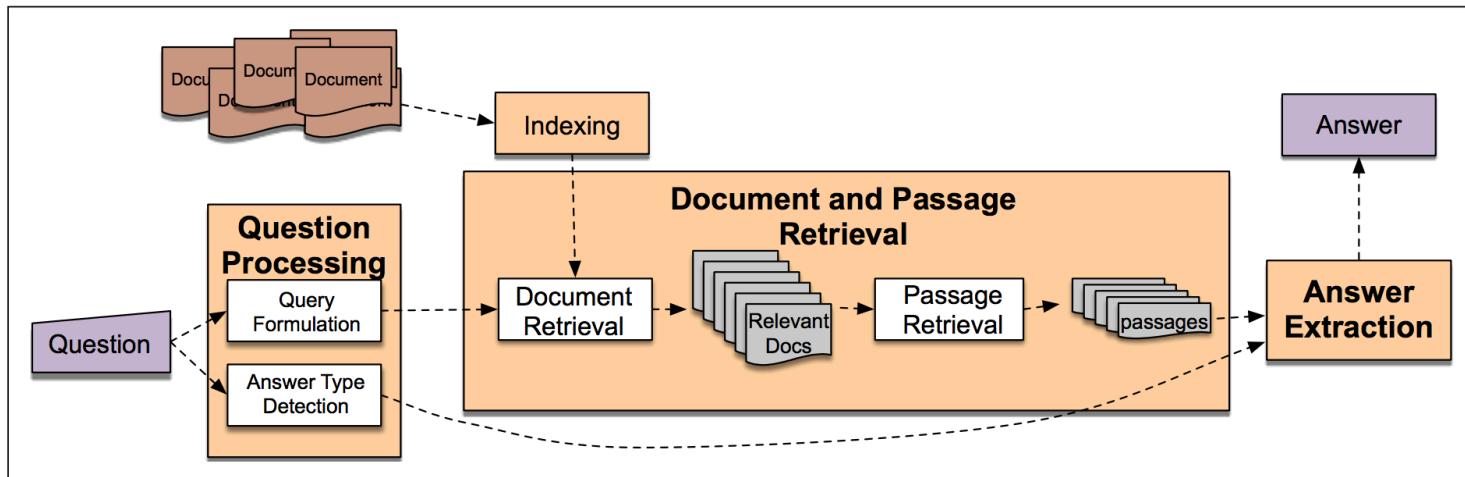


Figure 25.2 IR-based factoid question answering has three stages: question processing, passage retrieval, and answer processing.

Answer type detection

- If we know the type of answer expected for a question, we can exclude answers that aren't of that type (resulting in higher precision)

Who founded Virgin Airlines?	→	PERSON
What Canadian city has the largest population?	→	CITY

Answer type detection

ENTITY	
animal	What are the names of Odin's ravens?
body	What part of your body contains the corpus callosum?
color	What colors make up a rainbow?
creative	In what book can I find the story of Aladdin?
currency	What currency is used in China?
disease/medicine	What does Salk vaccine prevent?
event	What war involved the battle of Chapultepec?
food	What kind of nuts are used in marzipan?
instrument	What instrument does Max Roach play?
lang	What's the official language of Algeria?
letter	What letter appears on the cold-water tap in Spain?
other	What is the name of King Arthur's sword?
plant	What are some fragrant white climbing roses?
product	What is the fastest computer?
religion	What religion has the most members?
sport	What was the name of the ball game played by the Mayans?
substance	What fuel do airplanes use?
symbol	What is the chemical symbol for nitrogen?
technique	What is the best way to remove wallpaper?
term	How do you say " Grandma" in Irish?
vehicle	What was the name of Captain Bligh's ship?
word	What's the singular of dice?

Answer type detection

- Train an answer type detection system with supervised learning:
 - Words/embeddings
 - POS for each word
 - Question headword
 - Which **city** in China has the largest number of foreign financial companies?
 - What is the state **flower** of California?

Document retrieval

- Rather than running answer extraction on all documents, let's just focus on the subset that are likely to be **relevant**.
- This is a problem of **information retrieval**.

IR

- Represent query **and** each document by tf-idf weighted vector, rank by cosine similarity

$$\cos(x, y) = \frac{\sum_{i=1}^F x_i y_i}{\sqrt{\sum_{i=1}^F x_i^2} \sqrt{\sum_{i=1}^F y_i^2}}$$

term	doc 1	doc 2	doc 3
alaska			4.5
primary			7.8
dog		4.8	3.4
friday			
nlp	6.4		
the	0.05	0.03	0.02
dem			8.1
tree	2.3	9.1	

Document retrieval

- Answer extraction typically operates on passages (not entire documents), so we can rank the passages as well using information about:
 - Number of entities of correct type
 - Number of question keywords
 - Longest exact sequence of keywords in passage
 - Rank of document
 - Ngram overlap

Answer extraction

- From a given passage, extract the answer.

Input passage

Talking Heads were an American rock band formed in 1975 in New York City and active until 1991.^[8] The band comprised David Byrne (lead vocals, guitar), Chris Frantz (drums), Tina Weymouth (bass), and Jerry Harrison (keyboards, guitar). Described by the critic Stephen Thomas Erlewine as "one of the most critically acclaimed bands of the '80s,"^[3] the group helped to pioneer new wave music by integrating elements of punk, art rock, funk, and world music with avant-garde sensibilities and an anxious, clean-cut image.^[3]

Question

Where did the Talking Heads originate?

IR-based QA

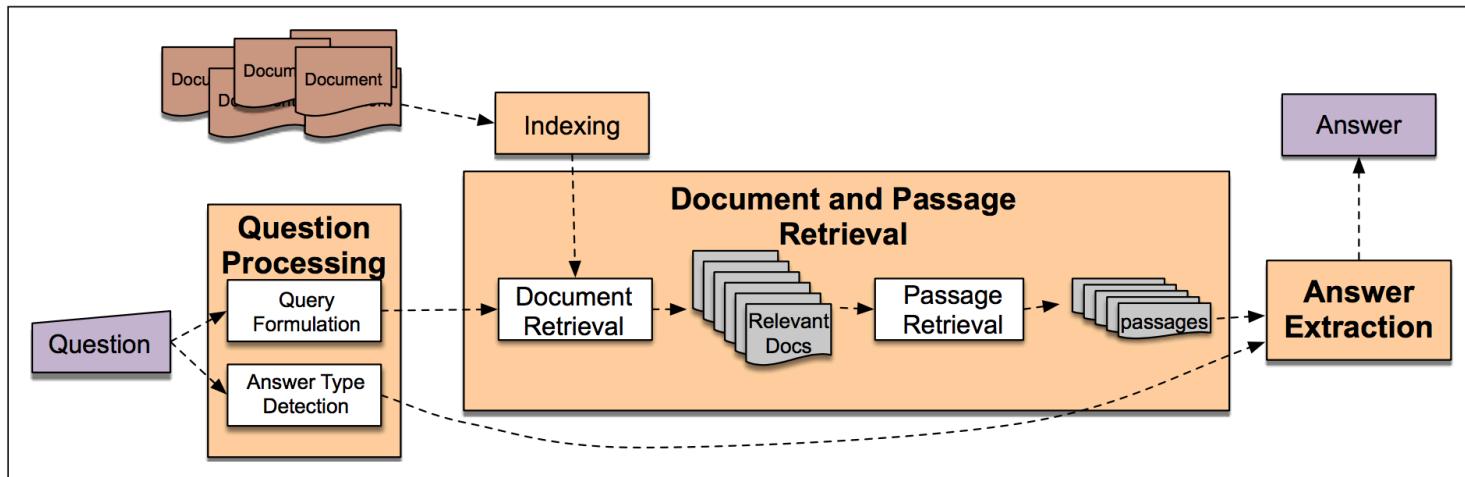


Figure 25.2 IR-based factoid question answering has three stages: question processing, passage retrieval, and answer processing.

Datasets

Dataset	Size	Source	Notes
SQuAD	150K	Wikipedia	
NewsQA	100K	CNN	
HotpotQA	113K	Wikipedia	Requires reasoning over multiple documents
NarrativeQA	46K	Books/movie scripts	Requires reasoning over long documents, answer not a span

HotpotQA

Paragraph A, Return to Olympus:

[1] *Return to Olympus* is the only album by the alternative rock band Malfunkshun. [2] It was released after the band had broken up and after lead singer Andrew Wood (later of Mother Love Bone) had died of a drug overdose in 1990. [3] Stone Gossard, of Pearl Jam, had compiled the songs and released the album on his label, Loosegroove Records.

Paragraph B, Mother Love Bone:

[4] *Mother Love Bone* was an American rock band that formed in Seattle, Washington in 1987. [5] The band was active from 1987 to 1990. [6] Frontman Andrew Wood's personality and compositions helped to catapult the group to the top of the burgeoning late 1980s/early 1990s Seattle music scene. [7] Wood died only days before the scheduled release of the band's debut album, "Apple", thus ending the group's hopes of success. [8] The album was finally released a few months later.

Q: What was the former band of the member of Mother Love Bone who died just before the release of "Apple"?

A: Malfunkshun

Supporting facts: 1, 2, 4, 6, 7

SQuAD

- 100,000 question-answer pairs created by crowdworkers.
- Task: given an input passage from Wikipedia, create a question whose answer is **a span of text within it**.

In meteorology, precipitation is any product of the condensation of atmospheric water vapor that falls under **gravity**. The main forms of precipitation include drizzle, rain, sleet, snow, **graupel** and hail... Precipitation forms as smaller droplets coalesce via collision with other rain drops or ice crystals **within a cloud**. Short, intense periods of rain in scattered locations are called "showers".

What causes precipitation to fall?
gravity

What is another main form of precipitation besides drizzle, rain, snow, sleet and hail?
graupel

Where do water droplets collide with ice crystals to form precipitation?
within a cloud

Figure 1: Question-answer pairs for a sample passage in the SQuAD dataset. Each of the answers is a segment of text from the passage.

SQuAD2.0

- 100K questions from SQuAD + 50K **unanswerable** questions.
- To perform well, models must know when to abstain from answering a question.

Article: Endangered Species Act

Paragraph: “*... Other legislation followed, including the Migratory Bird Conservation Act of 1929, a **1937 treaty** prohibiting the hunting of right and gray whales, and the **Bald Eagle Protection Act of 1940**. These **later laws** had a low cost to society—the species were relatively rare—and little **opposition** was raised.*”

Question 1: “Which laws faced significant **opposition**? ”

Plausible Answer: *later laws*

Question 2: “What was the name of the **1937 treaty**? ”

Plausible Answer: *Bald Eagle Protection Act*

Evaluation

- Exact match: proportion of questions for which the predicted answer is an exact match for the correct answer.
- F1: Calculate F1 between predicted answer and gold answer (both bag of tokens).

SQuAD2.0

Leaderboard

SQuAD2.0 tests the ability of a system to not only answer reading comprehension questions, but also abstain when presented with a question that cannot be answered based on the provided paragraph.

Rank	Model	EM	F1
	Human Performance Stanford University <i>(Rajpurkar & Jia et al. '18)</i>	86.831	89.452
1	FPNet (ensemble) <i>Ant Service Intelligence Team</i>	90.871	93.183
Feb 21, 2021			
2	IE-Net (ensemble) RICOH_SRCB_DML	90.758	93.044
Feb 24, 2021			
3	SA-Net on Albert (ensemble) QIANXIN	90.724	93.011
Apr 06, 2020			
4	SA-Net-V2 (ensemble) QIANXIN	90.679	92.948
May 05, 2020			
4	Retro-Reader (ensemble) Shanghai Jiao Tong University http://arxiv.org/abs/2001.09694	90.578	92.978
Apr 05, 2020			

Input passage

Talking Heads were an American **rock** band formed in 1975 in **New York City** and active until 1991.^[8] The band comprised **David Byrne** (**lead vocals, guitar**), **Chris Frantz** (**drums**), **Tina Weymouth** (**bass**), and **Jerry Harrison** (**keyboards**, **guitar**). Described by the critic **Stephen Thomas Erlewine** as "one of the most critically acclaimed bands of the '80s,"^[3] the group helped to pioneer **new wave music** by integrating elements of **punk**, **art rock**, **funk**, and **world music** with **avant-garde** sensibilities and an anxious, clean-cut image.^[3]

Question

Where did the Talking Heads originate?

- What is the **start token position** and **end token position** for the answer span in the input passage?

Featurized

- Answer type match: does the candidate answer contain a phrase with the answer type expected?
- Pattern match:

Pattern	Question	Answer
<AP> such as <QP>	What is autism?	“, <u>developmental disorders</u> such as autism”
<QP>, a <AP>	What is a caldera?	“the Long Valley caldera, a <u>volcanic crater</u> 19 miles long”

Figure 25.5 Some answer-extraction patterns using the answer phrase (AP) and question phrase (QP) for definition questions (Pasca, 2003).

Featurized

- Number of matched question keywords
- Keyword distance: distance between answer and query keywords
- Novelty factor: does the passage contain words that are not in the query?
- Length of longest sequence of question terms that occur in the candidate answer
- Apposition features: answer is in appositive construction to phrase containing several question words.
 - Question: What is a **caldera**?
 - Candidate: “the Long Valley **caldera**, **a volcanic crater 19 miles long**”

Neural (BERT)

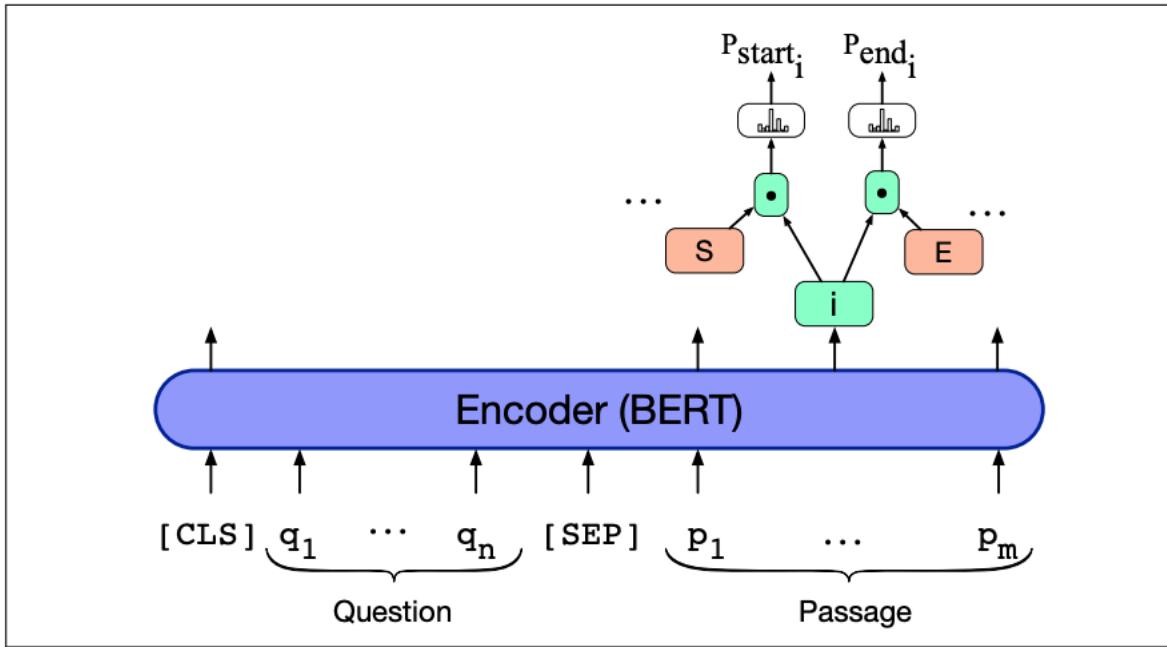


Figure 14.12 An encoder model (using BERT) for span-based question answering from reading-comprehension-based question answering tasks.

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Talking Heads were an American rock band formed in 1975 in New York City and active until 1991.

Question

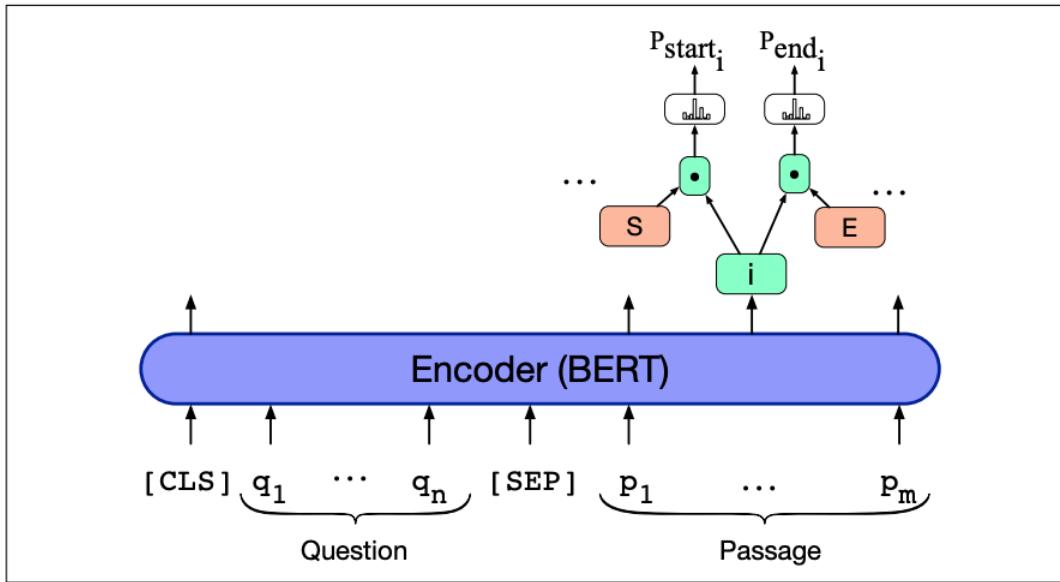
Where did the Talking Heads originate?

- What is the **start token position** and **end token position** for the answer span in the input passage?

$p_{\text{start}}(i)$	0	0	0	0	0.10	0	0	0	0
$p_{\text{end}}(i)$	0	0	0	0	0.09	0	0	0	0
Text	Talking	Heads	were	an	American	rock	band	formed	in

$p_{\text{start}}(i)$	0	0	0.85	0	0.05	0	0	0	0
$p_{\text{end}}(i)$	0	0	0	0.16	0.75	0	0	0	0
Text	1975	in	New	York	City	and	active	until	1991

- Each token position i has two associated probabilities:
 - $p_{\text{start}}(i)$ — the probability of the answer starting at that token.
 - $p_{\text{end}}(i)$ — the probability of the answer ending at that token.



$$P_{\text{start}_i} = \frac{\exp(S \cdot p'_i)}{\sum_j \exp(S \cdot p'_j)}$$

$$P_{\text{end}_i} = \frac{\exp(E \cdot p'_i)}{\sum_j \exp(E \cdot p'_j)}$$

Figure 14.12 An encoder model (using BERT) for span-based question answering from reading-comprehension-based question answering tasks.

LLM-based QA



You

which building is the oldest in UC-Berkeley



ChatGPT

The oldest building on the University of California, Berkeley campus is South Hall. Constructed in 1873, South Hall is a historic landmark and one of the original buildings of the university. It served as the university's main administrative and academic building in its early years. Today, South Hall continues to be used for academic purposes and is recognized as an important symbol of UC Berkeley's history and heritage.

Everything is language modeling

The director of *2001: A Space Odyssey* is _____

The French translation of “cheese” is _____

The sentiment of “I really hate this movie” is _____

In Context Learning

- Provide the pattern; LLM is expected to continue with it.
- Use the off-the-shelf model:
 - No Gradient update and parameter change.

Prompting a question

- Provide the pattern; LLM is expected to continue with it.

$$p(x_1, \dots, x_n) = \prod_{i=1}^n p(x_i | x_{<i})$$

Q: Who wrote the book ‘‘The Origin of Species”? A:

$$p(x_1, \dots, x_n) = \prod_{i=1}^n p([Q:] ; q ; [A:] ; x_{<i})$$

Retrieval Augmented Generation (RAG)

retrieved passage 1

retrieved passage 2

...

retrieved passage n

Based on these texts, answer this question: Q: Who wrote the book "The Origin of Species"? A:

$$p(x_1, \dots, x_n) = \prod_{i=1}^n p(x_i | R(q); \text{prompt}; [\text{Q}:]; q; [\text{A}:]; x_{<i})$$

Multi-hop QA

- We mostly focused on factoid questions
- Multi-hop QA:
 - Splitting
 - Multi-step Updating of the prompt

Paragraph A, Return to Olympus:

[1] *Return to Olympus* is the only album by the alternative rock band Malfunkshun. [2] It was released after the band had broken up and after lead singer Andrew Wood (later of Mother Love Bone) had died of a drug overdose in 1990. [3] Stone Gossard, of Pearl Jam, had compiled the songs and released the album on his label, Loosegroove Records.

Paragraph B, Mother Love Bone:

[4] *Mother Love Bone* was an American rock band that formed in Seattle, Washington in 1987. [5] The band was active from 1987 to 1990. [6] Frontman Andrew Wood's personality and compositions helped to catapult the group to the top of the burgeoning late 1980s/early 1990s Seattle music scene. [7] Wood died only days before the scheduled release of the band's debut album, "Apple", thus ending the group's hopes of success. [8] The album was finally released a few months later.

Q: What was the former band of the member of Mother Love Bone who died just before the release of "Apple"?

A: Malfunkshun

Supporting facts: 1, 2, 4, 6, 7