CS 6120/CS4120: Natural Language Processing

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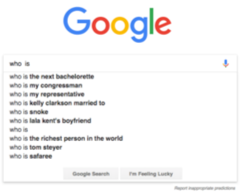
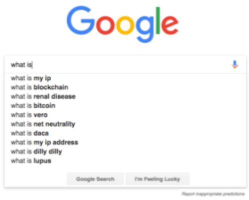
Logistics

- This Friday (3/2): no class, but you can come to my office (258WVH) 3:25pm-5:05pm if you have any questions
- Assignment 1 grading is almost done!
- Some submission problem to avoid in assignment 2:
  - No README
  - Code running error

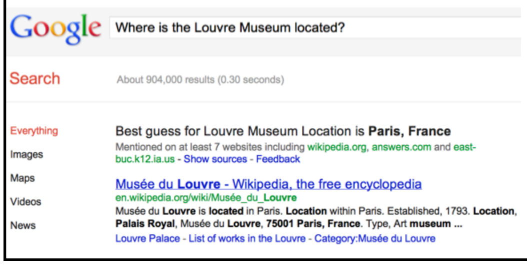
Question Answering

IR-based Question Answering


who is
who is the next bachelorette
who is my congressman
who is my representative
who is kelly clarkson married to
who is snoke
who is lala kent's boyfriend
who is
who is the richest person in the world
who is tom steyer
who is safaree


what is
what is my ip
what is blockchain
what is renal disease
what is bitcoin
what is vero
what is net neutrality
what is daca
what is my ip address
what is dilly dilly
what is lupus

IR-based Question Answering


Where is the Louvre Museum located?

About 904,000 results (0.30 seconds)

Best guess for Louvre Museum Location is **Paris, France**
Mentioned on at least 7 websites including wikipedia.org, answers.com and east-buc.k12.ia.us - Show sources - Feedback

Musée du **Louvre** - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Musée_du_Louvre
Musée du **Louvre** is **located** in Paris. **Location** within Paris. Established, 1793. **Location**, **Palais Royal**, Musée du **Louvre**, **75001 Paris, France**. Type, Art **museum** ...
Louvre Palace - List of works in the Louvre - Category:Musée du Louvre

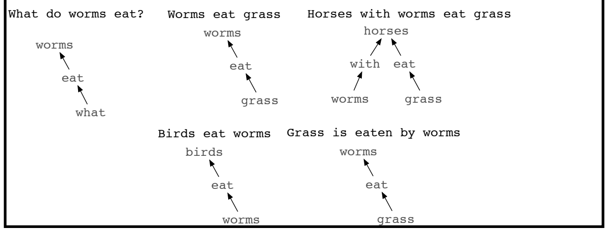
Question Answering

One of the oldest NLP tasks (punched card systems in 1961)

Question:

Potential Answers:

Simmons, Klein, McConlogue. 1964. Indexing and Dependency Logic for Answering English Questions. American Documentation 15:30, 196-204


What do worms eat?
worms
eat
what

Worms eat grass
worms
eat
grass

Horses with worms eat grass
horses
with
eat
worms
grass

Birds eat worms
birds
eat
worms

Grass is eaten by worms
worms
eat
grass

Question Answering

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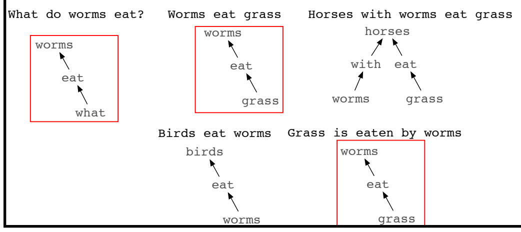
Question: Potential Answers:



What do worms eat?

worms ← eat ← what

Worms eat grass

worms ← eat ← grass

Horses with worms eat grass

horses ← with ← worms; horses ← eat ← grass

Birds eat worms

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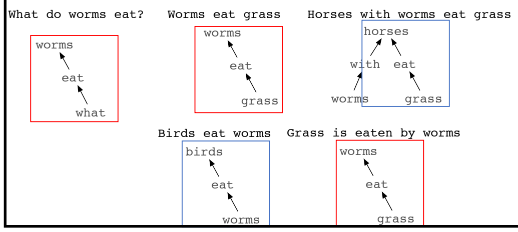

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Birds eat worms

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Grass is eaten by worms

worms ← eat ← grass

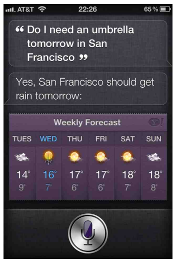
Question Answering: IBM's Watson

- Won Jeopardy on February 16, 2011!

WILLIAM WILKINSON'S
"AN ACCOUNT OF THE PRINCIPALITIES OF
WALLACHIA AND MOLDOVIA"
INSPIRED THIS AUTHOR'S
MOST FAMOUS NOVEL

→ Bram Stoker

Apple's Siri



AT&T 22:26 65 %

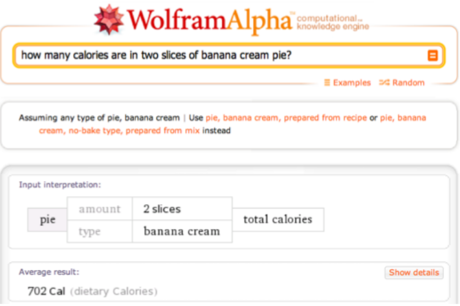
❝ Do I need an umbrella tomorrow in San Francisco ❞

Yes, San Francisco should get rain tomorrow:

Weekly Forecast

TUES	WED	THU	FRI	SAT	SUN
14°	16°	17°	17°	18°	18°
9°	7°	6°	6°	7°	8°

Wo



WolframAlpha computational knowledge engine

how many calories are in two slices of banana cream pie?

Assuming any type of pie, banana cream | Use pie, banana cream, prepared from recipe or pie, banana cream, no-bake type, prepared from mix instead

Input interpretation:

pie	amount	2 slices	total calories
	type	banana cream	

Average result:

702 Cal (dietary Calories)

Types of Questions in Modern Systems

- Factoid questions
  - *Who wrote "The Universal Declaration of Human Rights"?*
  - *How many calories are there in two slices of apple pie?*
  - *What is the average age of the onset of autism?*
  - *Where is Apple Computer based?*
- Complex (narrative) questions:
  - *In children with an acute febrile illness, what is the efficacy of acetaminophen in reducing fever?*
  - *What do scholars think about Jefferson's position on dealing with pirates?*

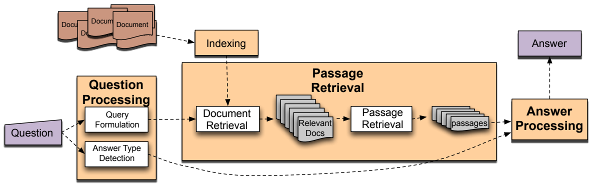
Commercial systems: mainly factoid questions

Where is the Louvre Museum located?	In Paris, France
What's the abbreviation for limited partnership?	L.P.
What are the names of Odin's ravens?	Huginn and Muninn
What currency is used in China?	The yuan
What kind of nuts are used in marzipan?	almonds
What instrument does Max Roach play?	drums

Paradigms for QA

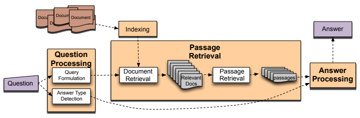
- Information Retrieval (IR)-based approaches
  - TREC; IBM Watson; Google
- Knowledge-based and Hybrid approaches
  - IBM Watson; Apple Siri; Wolfram Alpha
- Data-driven, neural network-based approaches

IR-based Factoid QA



IR-based Factoid QA

- QUESTION PROCESSING
  - Detect question type, answer type, focus, relations
    - ”Who is the president of US?”-> person
  - Formulate queries to send to a search engine
    - “president of United States”
- PASSAGE RETRIEVAL
  - Retrieve ranked documents
  - Break into suitable passages and rerank
- ANSWER PROCESSING
  - Extract candidate answers
  - Rank candidates
    - using evidence from the text and external sources



Knowledge-based approaches (Siri)

- Build a semantic representation of the query
  - Times, dates, locations, entities, numeric quantities
- Map from this semantics to query structured data or resources
  - Geospatial databases
  - Ontologies (Wikipedia infoboxes, dbPedia, WordNet, Yago)
  - Restaurant review sources and reservation services
  - Scientific databases

Hybrid approaches (IBM Watson)

- Build a shallow semantic representation of the query
- Generate answer candidates using IR methods
  - Augmented with ontologies and semi-structured data
- Score each candidate using richer knowledge sources
  - Geospatial databases
  - Temporal reasoning
  - Taxonomical classification

Answer Types and Query Formulation

IR-based Factoid QA

- QUESTION PROCESSING
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    - "Who is the president of US?"-> person
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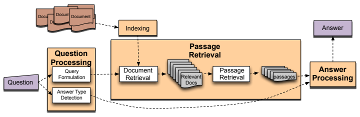


Question Processing
Things to extract from the question

- Answer Type Detection
  - Decide the **named entity type** (person, place) of the answer
- Query Formulation
  - Choose **query keywords** for the IR system
- Question Type classification
  - Is this a definition question, a math question, a list question?
- Focus Detection
  - Find the question words that are replaced by the answer
- Relation Extraction
  - Find relations between entities in the question

Question Processing

Jeopardy!: They're the two states you could be reentering if you're crossing Florida's northern border

You should answer: what are the states of Georgia and Alabama?

- Answer Type: US state
- Query Formulation: two states, border, Florida, north
- Focus: the two states
- Relations: borders(Florida, ?x, north)

Answer Type Detection: Named Entities

- *Who founded Virgin Airlines?*

Answer Type Detection: Named Entities

- *Who founded Virgin Airlines?*
  - PERSON
- *What Canadian city has the largest population?*

Answer Type Detection: Named Entities

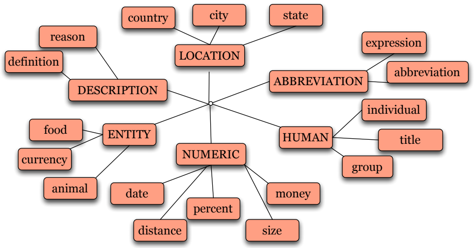
- *Who founded Virgin Airlines?*
  - PERSON
- *What Canadian city has the largest population?*
  - CITY

Answer Type Taxonomy

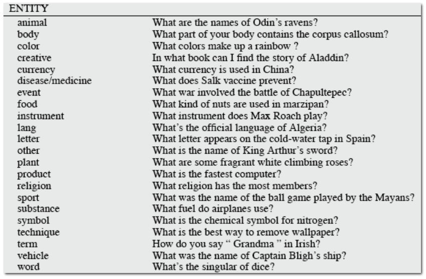
Xin Li, Dan Roth. 2002. Learning Question Classifiers. COLING'02

- 6 coarse classes
  - ABBREVIATION, ENTITY, DESCRIPTION, HUMAN, LOCATION, NUMERIC
- 50 finer classes
  - LOCATION: city, country, mountain…
  - HUMAN: group, individual, title, description
  - ENTITY: animal, body, color, currency…

Part of Li & Roth's Answer Type Taxonomy

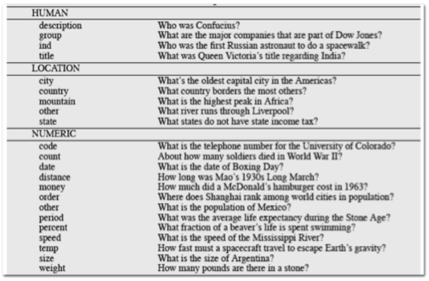


Answer Types



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?

More Answer Types



HUMAN	
description	Who was Confucius?
group	What are the major companies that are part of Dow Jones?
ind	Who was the first Russian astronaut to do a spacewalk?
title	What was Queen Victoria's title regarding India?
LOCATION	
city	What's the oldest capital city in the Americas?
country	What country borders the most others?
mountain	What is the highest peak in Africa?
other	What river runs through Liverpool?
state	What states do not have state income tax?
NUMERIC	
code	What is the telephone number for the University of Colorado?
count	About how many soldiers died in World War II?
date	What is the date of Boxing Day?
distance	How long was Mao's 1930s Long March?
money	How much did a McDonald's hamburger cost in 1963?
order	Where does Shanghai rank among world cities in population?
other	What is the population of Mexico?
period	What was the average life expectancy during the Stone Age?
percent	What fraction of a beaver's life is spent swimming?
speed	What is the speed of the Mississippi River?
temp	How fast must a spacecraft travel to escape Earth's gravity?
size	What is the size of Argentina?
weight	How many pounds are there in a stone?

Answer types in Jeopardy

Ferrucci et al. 2010. Building Watson: An Overview of the DeepQA Project. AI Magazine. Fall 2010. 59-79.

- 2500 answer types in 20,000 Jeopardy question sample
- The most frequent 200 answer types cover < 50% of data
- The 40 most frequent Jeopardy answer types

he, country, city, man, film, state, she, author, group, here, company, president, capital, star, novel, character, woman, river, island, king, song, part, series, sport, singer, actor, play, team, show, actress, animal, presidential, composer, musical, nation, book, title, leader, game

Answer Type Detection

- Hand-written rules
- Machine Learning
- Hybrids

Answer Type Detection

- Regular expression-based rules can get some cases:
  - Who {is|was|are|were} PERSON
  - PERSON (YEAR – YEAR)
- Other rules use the **question headword**:
  (the headword of the first noun phrase after the wh-word)
  - Which **city** in China has the largest number of foreign financial companies?
  - What is the state **flower** of California?

Answer Type Detection

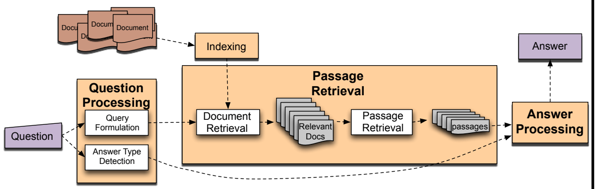
- Most often, we treat the problem as machine learning classification
  - **Define** a taxonomy of question types
  - **Annotate** training data for each question type
  - **Train** classifiers for each question class using a rich set of features.
    - features include those hand-written rules!

Features for Answer Type Detection

- Question words and phrases
- Part-of-speech tags
- Parse features (headwords)
- Named Entities
- Semantically related words

Which **city** in China has the largest number of foreign financial companies?
What is the state **flower** of California?

Factoid Q/A



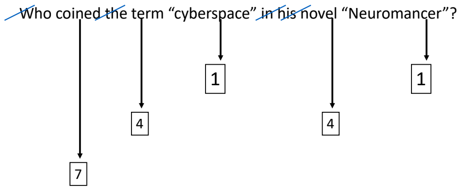
Keyword Selection Algorithm

Dan Moldovan, Sanda Harabagiu, Marius Paca, Rada Mihalcea, Richard Goodrum, Roxana Girju and Vasile Rus. 1999. Proceedings of TREC-8.

1. Select all non-stop words in quotations
2. Select all NNP words in recognized named entities
3. Select all complex nominals with their adjectival modifiers
4. Select all other complex nominals
5. Select all nouns with their adjectival modifiers
6. Select all other nouns
7. Select all verbs
8. Select all adverbs
9. Select the question focus word (skipped in all previous steps)
10. Select all other words

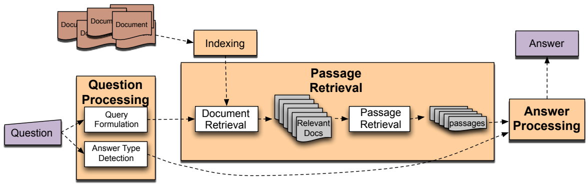
Choosing keywords from the query

Slide from Mihai Surdeanu


~~Who~~ coined ~~the~~ term “cyberspace” ~~in his~~ novel “Neuromancer”?

cyberspace/1 Neuromancer/1 term/4 novel/4 coined/7

Factoid Q/A



Passage Retrieval and Answer Extraction

Passage Retrieval

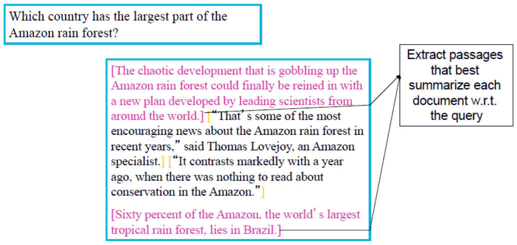
- Step 1: IR engine retrieves documents using query terms
- Step 2: Segment the documents into shorter units
  - something like paragraphs
- Step 3: Passage ranking
  - Use answer type to help rerank passages

Features for Passage Ranking

Either in rule-based classifiers or with supervised machine learning

- Number of Named Entities of the right type in passage
- Number of query words in passage
- Number of question N-grams also in passage
- Proximity of query keywords to each other in passage
- Longest sequence of question words
- Rank of the document containing passage

Passage Retrieval as Query-focused Summarization


Which country has the largest part of the Amazon rain forest?

[The chaotic development that is gobbling up the Amazon rain forest could finally be reined in with a new plan developed by leading scientists from around the world.] [“That’s some of the most encouraging news about the Amazon rain forest in recent years,” said Thomas Lovejoy, an Amazon specialist.] [“It contrasts markedly with a year ago, when there was nothing to read about conservation in the Amazon.”]

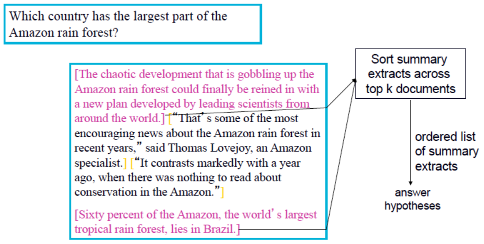
[Sixty percent of the Amazon, the world’s largest tropical rain forest, lies in Brazil.]

Extract passages that best summarize each document w.r.t. the query

Passage Retrieval as Query-focused Summarization

- Decide on a summary length (10% of document length).
- Use standard ad-hoc retrieval algorithm to retrieve top k documents.
- Treat each sentence/paragraph in top N documents as a document itself.
  - Use standard document similarity equations to assign a similarity score to the sentence/paragraph.
- Return highest-scoring sentences/paragraphs as the summary, subject to the length constraint.

Passage Retrieval as Query-focused Summarization



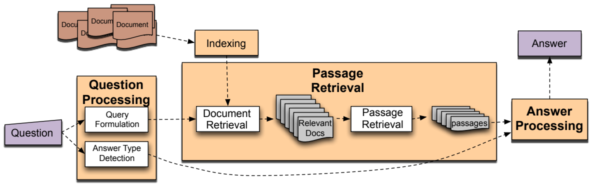
Which country has the largest part of the Amazon rain forest?

[The chaotic development that is gobbling up the Amazon rain forest could finally be reined in with a new plan developed by leading scientists from around the world.] [“That’ s some of the most encouraging news about the Amazon rain forest in recent years,” said Thomas Lovejoy, an Amazon specialist.] [“It contrasts markedly with a year ago, when there was nothing to read about conservation in the Amazon.”]

[Sixty percent of the Amazon, the world’ s largest tropical rain forest, lies in Brazil.]

Sort summary extracts across top k documents
ordered list of summary extracts
answer hypotheses

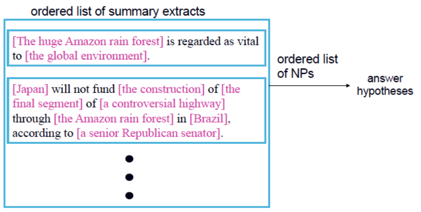
Factoid Q/A



Answer Extraction

- Run an answer-type named-entity tagger on the passages
  - Each answer type requires a named-entity tagger that detects it
  - If answer type is CITY, tagger has to tag CITY
    - Can be full NER, simple regular expressions, or hybrid
- Return the string with the right type:
  - `Who is the prime minister of India` (PERSON)
    `**Manmohan Singh**, Prime Minister of India, had told left leaders that the deal would not be renegotiated.`
  - `How tall is Mt. Everest?` (LENGTH)
    `The official height of Mount Everest is **29035 feet**`

The noun phrase filter



ordered list of summary extracts

[The huge Amazon rain forest] is regarded as vital to [the global environment].

[Japan] will not fund [the construction] of [the final segment] of [a controversial highway] through [the Amazon rain forest] in [Brazil], according to [a senior Republican senator].

•
•
•

Adding Analysis Patterns

- “Who is Elvis?”
  - Question type: “who”
  - Named-entity tagging: “Who is <personname> Elvis</person-name>”
  - Analysis pattern: if question type = “who” and question contains <person-name> then
- Desired answer probably is a description
- Likely answer extraction patterns
  - “Elvis, the X”, e.g., “Elvis, the *king of rock and roll*!”
  - “the X Elvis”, e.g., “the *legendary entertainer* Elvis”

Ranking Candidate Answers

- But what if there are multiple candidate answers!

`Q: Who was Queen Victoria's second son?`

- Answer Type: **Person**

- Passage:

The Marie biscuit is named after Marie Alexandrovna, the daughter of Czar Alexander II of Russia and wife of Alfred, the second son of Queen Victoria and Prince Albert

Ranking Candidate Answers

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- Answer Type: **Person**

- Passage:

The Marie biscuit is named after **Marie Alexandrovna**, the daughter of **Czar Alexander II of Russia** and wife of **Alfred**, the second son of **Queen Victoria** and **Prince Albert**

Use machine learning: Features for ranking candidate answers

Answer type match: Candidate contains a phrase with the correct answer type.

Pattern match: Regular expression pattern matches the candidate.

Question keywords: # of question keywords in the candidate.

Keyword distance: Distance in words between the candidate and query keywords

Novelty factor: A word in the candidate is not in the query.

Apposition features: The candidate is an appositive to question terms

Punctuation location: The candidate is immediately followed by a comma, period, quotation marks, semicolon, or exclamation mark.

Sequences of question terms: The length of the longest sequence of question terms that occurs in the candidate answer.

Candidate Answer scoring in IBM Watson

- Each candidate answer gets scores from >50 components
  - (from unstructured text, semi-structured text, triple stores)
  - logical form (parse) match between question and candidate
  - passage source reliability
  - geospatial location
    - California is "southwest of Montana"
  - temporal relationships
  - taxonomic classification

Common Evaluation Metrics

1. *Accuracy* (does answer match gold-labeled answer?)
2. *Mean Reciprocal Rank*
   - For each query return a ranked list of M candidate answers.
   - Query score is 1/Rank of the first correct answer
     - *If first answer is correct: 1*
     - *else if second answer is correct: ½*
     - *else if third answer is correct: ⅓, etc.*
     - *Score is 0 if none of the M answers are correct*
   - Take the mean over all N queries

$$MRR = \frac{\sum_{i=1}^{N} \frac{1}{rank_i}}{N}$$

Knowledge in QA

Relation Extraction

- Answers: Databases of Relations
  - born-in(“Emma Goldman”, “June 27 1869”)
  - author-of(“Cao Xue Qin”, “Dream of the Red Chamber”)
  - Draw from Wikipedia infoboxes, DBpedia, FreeBase, etc.
- Questions: Extracting Relations in Questions

  Whose granddaughter starred in E.T.?

```
(acted-in ?x “E.T.”)
   (granddaughter-of ?x ?y)
```

Temporal Reasoning

- Relation databases
  - (and obituaries, biographical dictionaries, etc.)
- IBM Watson

  ”In 1594 he took a job as a tax collector in Andalusia”

  Candidates:
  - Thoreau is a bad answer (born in 1817)
  - Cervantes is possible (was alive in 1594)

Context and Conversation in Virtual Assistants like Siri

- Coreference helps resolve ambiguities

  U: “Book a table at Il Fornaio at 7:00 with **my mom**”

  U: “Also send **her** an email reminder”
- Clarification questions:

  U: “Chicago pizza”

  S: “Did you mean pizza restaurants in Chicago or Chicago-style pizza?”

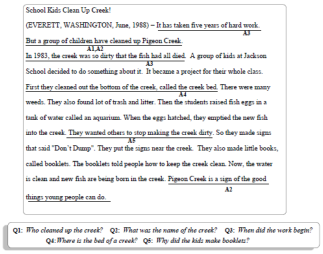
Limitations of Factoid Q/A

- Question must query a specific fact that is explicitly stated somewhere in the document corpus.
- Does not allow aggregating or accumulating information across multiple information sources.
- Does not require “deep compositional” semantics, nor inferential reasoning to generate answer.

Reading Comprehension Q/A

- Answer questions that test comprehension of a specific document.
- Use standardized tests of reading comprehension to evaluate performance (Hirschman et al. 1999; Rilo & Thelen, 2000; Ng et al. 2000; Charniak et al. 2000).

Sample Reading Comprehension Test



School Kids Clean Up Creek!

(EVERETT, WASHINGTON, June, 1988) – It has taken five years of hard work. A3

But a group of children have cleaned up Pigeon Creek. A1,A2

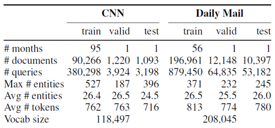
In 1983, the creek was so dirty that the fish had all died. A3 A group of kids at Jackson School decided to do something about it. It became a project for their whole class. First they cleaned out the bottom of the creek, called the creek bed. A4 There were many weeds. They also found lot of trash and litter. Then the students raised fish eggs in a tank of water called an aquarium. When the eggs hatched, they emptied the new fish into the creek. They wanted others to stop making the creek dirty. A5 So they made signs that said "Don't Dump". They put the signs near the creek. They also made little books, called booklets. The booklets told people how to keep the creek clean. Now, the water is clean and new fish are being born in the creek. Pigeon Creek is a sign of the good things young people can do. A2

Q1: *Who cleaned up the creek?* **Q2:** *What was the name of the creek?* **Q3:** *When did the work begin?* **Q4:** *Where is the bed of a creek?* **Q5:** *Why did the kids make booklets?*

Fig. 6. A REMEDIA story annotated with answers. The five questions Q1-Q5 are also listed. The A1-A5 annotations in correspond to the questions Q1-Q5.

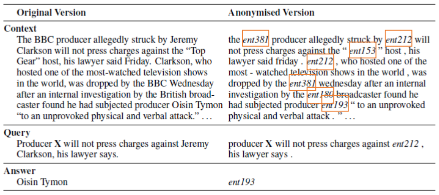
Large Scale Reading Comprehension Data

- DeepMind's large-scale data for reading comprehension Q/A (Hermann et al., 2015).
  - News articles used as source documents.
  - Questions constructed automatically from article summary sentences.



	CNN			Daily Mail		
	train	valid	test	train	valid	test
# months	95	1	1	56	1	1
# documents	90,266	1,220	1,093	196,961	12,148	10,397
# queries	380,298	3,924	3,198	879,450	64,835	53,182
Max # entities	527	187	396	371	232	245
Avg # entities	26.4	26.5	24.5	26.5	25.5	26.0
Avg # tokens	762	763	716	813	774	780
Vocab size	118,497			208,045		

Sample DeepMind Reading Comprehension Test

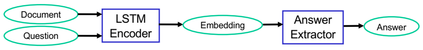


	Original Version	Anonymised Version
Context	The BBC producer allegedly struck by Jeremy Clarkson will not press charges against the "Top Gear" host, his lawyer said Friday. Clarkson, who hosted one of the most-watched television shows in the world, was dropped by the BBC Wednesday after an internal investigation by the British broadcaster found he had subjected producer Oisin Tymon "to an unprovoked physical and verbal attack." …	the *ent381* producer allegedly struck by *ent212* will not press charges against the " *ent153* " host , his lawyer said friday . *ent212* , who hosted one of the most - watched television shows in the world , was dropped by the *ent381* wednesday after an internal investigation by the *ent180* broadcaster found he had subjected producer *ent193* " to an unprovoked physical and verbal attack . " …
Query	Producer **X** will not press charges against Jeremy Clarkson, his lawyer says.	producer **X** will not press charges against *ent212* , his lawyer says .
Answer	Oisin Tymon	*ent193*

Table 3: Original and anonymised version of a data point from the Daily Mail validation set. The anonymised entity markers are constantly permuted during training and testing.

Deep LSTM Reader

- DeepMind uses LSTM recurrent neural net (RNN) to encode document and query into a vector that is then used to predict the answer.

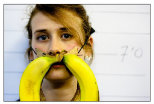


Incorporated various forms of attention to focus the reader on answering the question while reading the document.

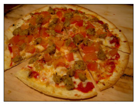
Visual Question Answering (VQA)

- Answer natural language questions about information in images.
- VaTech/MSR group has put together VQA dataset with ~750K questions over ~250K images (Antol et al., 2016).

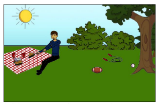
VQA Examples



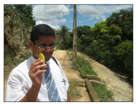
What color are her eyes?
What is the mustache made of?



How many slices of pizza are there?
Is this a vegetarian pizza?

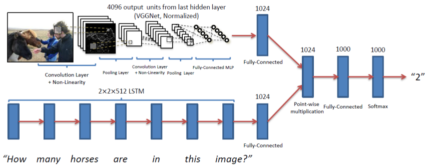


Is this person expecting company?
What is just under the tree?



Does it appear to be rainy?
Does this person have 20/20 vision?

LSTM System for VQA


4096 output units from last hidden layer
(VGGNet, Normalized)
Convolution Layer
+ Non-Linearity
Pooling Layer
Convolution Layer
+ Non-Linearity
Pooling Layer
Fully-Connected MLP
1024
Fully-Connected
1024
Point-wise multiplication
1000
Fully-Connected
1000
Softmax
"2"
2×2×512 LSTM
1024
Fully-Connected
"How
many
horses
are
in
this
image?"