

# Dialogue Systems

Allan Hanbury

# Literature

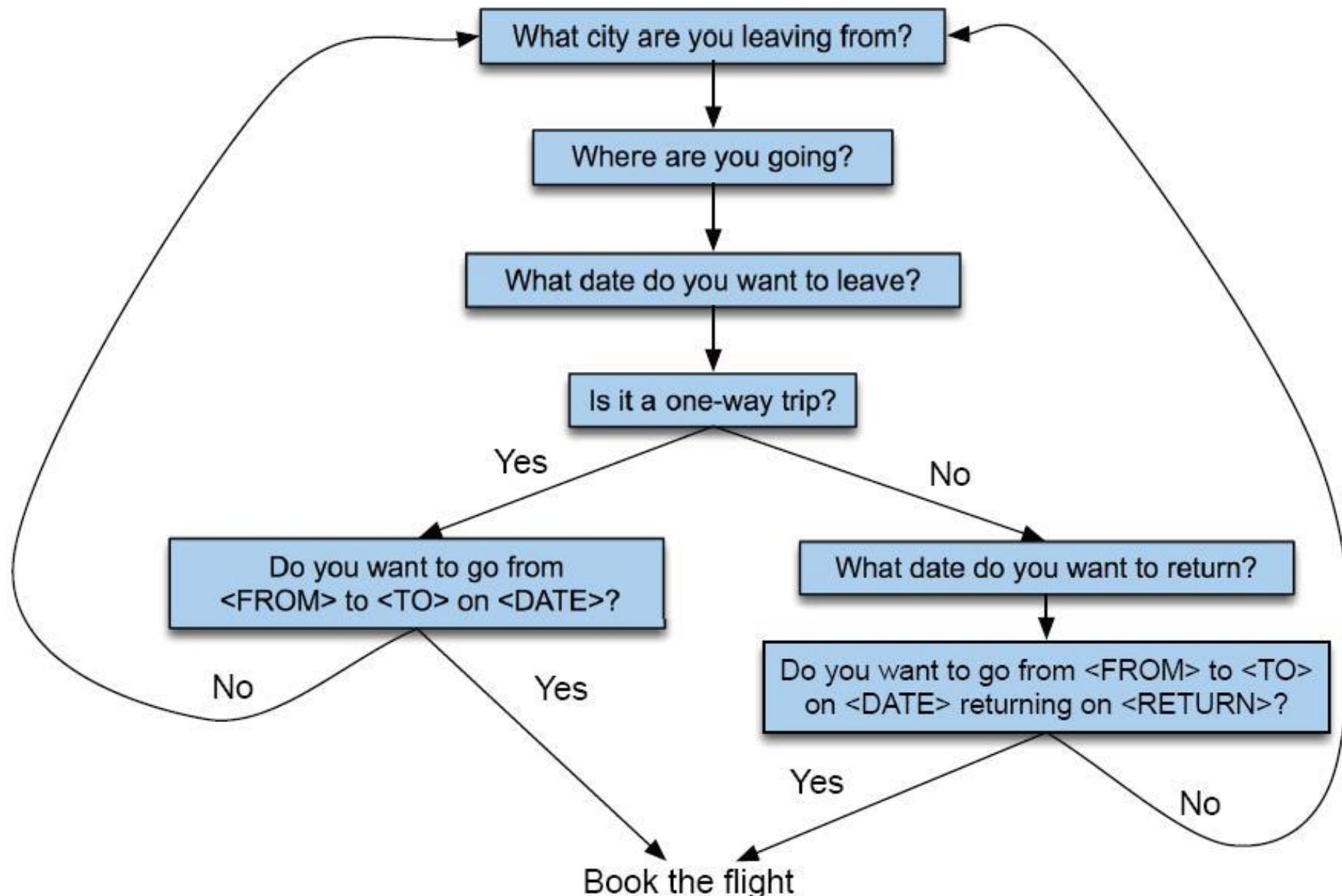
- Jurafsky and Martin book, Chapters 23 and 24
- Jianfeng Gao, Michel Galley and Lihong Li (2019), "Neural Approaches to Conversational AI", Foundations and Trends® in Information Retrieval: Vol. 13: No. 2-3, pp 127-298. <http://dx.doi.org/10.1561/1500000074>

# Contents

- Introduction
- Functions of Dialogue Systems
  - Task Completion
  - Question Answering
  - Social Chat
- Evaluation
- Ethical Aspects

# Introduction

# Finite State Dialog Manager



# Finite-state dialog managers

- System completely controls the conversation with the user.
- It asks the user a series of questions
- Ignoring (or misinterpreting) anything the user says that is not a direct answer to the system's questions

# Dialogue Initiative

- Systems that control conversation like this are called **single initiative**.
- **Initiative**: who has control of conversation
- In normal human-human dialogue, initiative shifts back and forth between participants.

# System Initiative

System completely controls the conversation



- Simple to build
  - User always knows what they can say next
  - System always knows what user can say next
    - Known words: Better performance from ASR
    - Known topic: Better performance from NLU
  - OK for VERY simple tasks (entering a credit card, or login name and password)
- 
- - Too limited

# Problems with System Initiative

- Real dialogue involves give and take!
- In travel planning, users might want to say something that is not the direct answer to the question
- For example answering more than one question in a sentence:

Hi, I'd like to fly from Seattle Tuesday morning

I want a flight from Milwaukee to Orlando one way leaving after  
5 p.m. on Wednesday.

# Single initiative + universals

- We can give users a little more flexibility by adding **universals**: commands you can say anywhere
- As if we augmented every state with these
  - Help**
  - Start over**
  - Correct**
- This describes many implemented systems
- But still doesn't allow user much flexibility

# Medical symptom checkers use this approach (1)



Hello, how can I help yo

OK, what symptom would you like to check?

If you have more than one, search for the symptom that's bothering you most.

Enter a symptom

e.g. headache

Clear

I have back pain

Common Searches

Headache

Abdominal pain

Tummy pain

Cough

Muscle pain

Sore throat

Ear pain

Dizziness

Where is your back pain?

Lower back

Upper back

Is your lower back pain worse when you move around?

Yes



No



How long have you had all of your symptoms for?

Have you noticed any numbness or feeling in the following places?

For minutes

For hours

For days

For weeks

For months

I don't know

- Face
- Hands
- Legs
- Feet
- None of the above
- I don't know

Continue

These could be signs of something serious. Patients with similar symptoms (Unilateral numbness of lower limb) usually require urgent evaluation by a doctor in the Emergency Department.

Patients with similar symptoms are usually advised to call 999, or local emergency services if you are outside the country, to get an ambulance.

Advice on coronavirus (COVID-19)

Common symptoms of coronavirus are:

- A new, continuous cough
- Fever
- Difficulty breathing
- Loss or change to your sense of taste or smell

Most people with coronavirus have at least one of these symptoms.

For the latest updates and information, read the Babylon guide at: <https://www.babylonhealth.com/coronavirus>

## A1 Chat

? – X

Kara hat den Chat betreten.

Aktuell kommt es bei der Zustellung von Post-Paketen zu Lieferverzögerungen.  
Details zu Ihrem Paket:  
<https://www.post.at/sv/sendungssuche>

10:17

Guten Morgen, ich bin Kara und antworte automatisiert auf deine Fragen.

10:17

Wie kann ich dir weiterhelfen?

10:17



Ich möchte meinen Vertrag kündigen

10:18

Schade, dass du dein A1 Festnetz Internet Produkt kündigen möchtest.

10:18

Aus welchem der folgenden Gründe willst du kündigen?

10:18



Langeweile  
10:18

Das hab ich leider so nicht verstanden.  
Damit ich dich bei diesem Thema unterstützen kann, beantworte mir bitte folgende Frage.

10:18

Was ist der Grund deiner Kündigung?

10:18

Produktqualität

Preis

Kundenservice

Umzug

Nutzungshäufigkeit

Keine Angabe



# Mixed Initiative: Potential human-agent dialogue

Social Chat

Question Answering

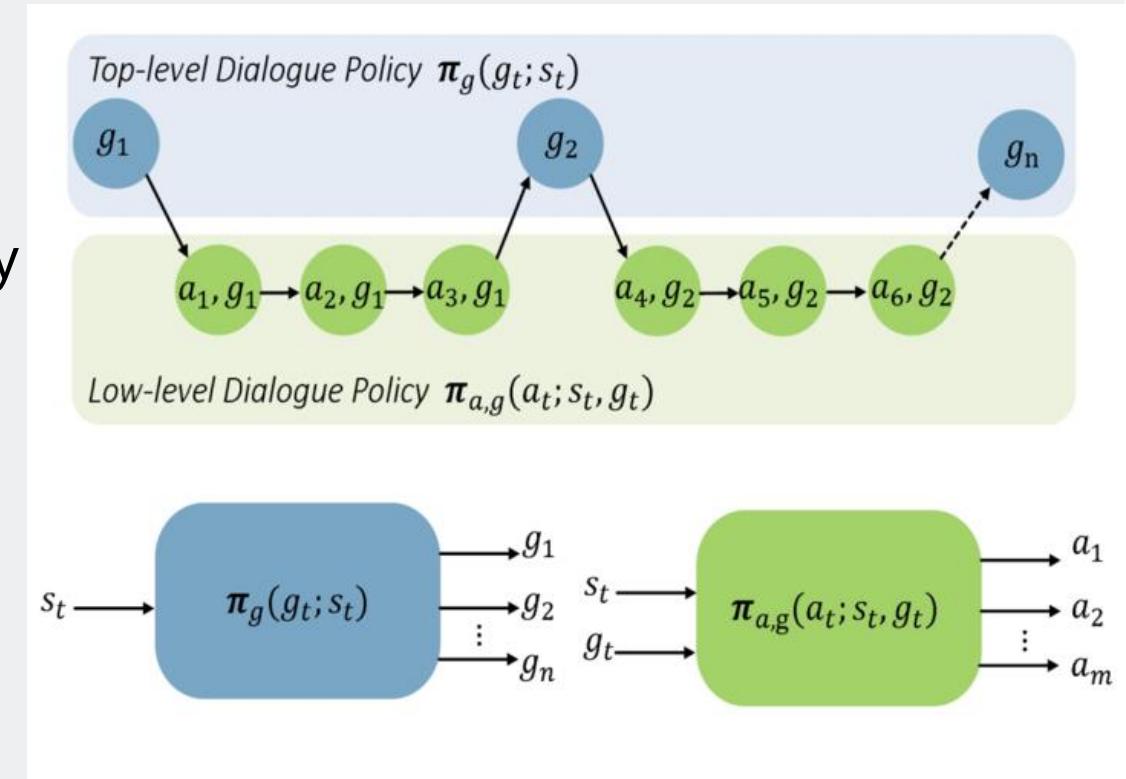
Task Completion

TU  
WIEN  
Informatics

Turn	Dialogue
1	<i>usr:</i> Good morning!
	<i>agt:</i> Good morning, I hope you had a great weekend.
2	<i>usr:</i> not really.
	<i>agt:</i> You sound depressed. What can I do for you?
3	<i>usr:</i> I'd like to know where sales are lagging behind our forecast?
	<i>agt:</i> The worst region is [country], where sales are 15% below projections.
4	<i>usr:</i> Do you know why?
	<i>agt:</i> The forecast for [product] growth was overly optimistic.
5	<i>usr:</i> How can we turn this around?
	<i>agt:</i> Here are the 10 customers in [country] with the most growth potential, per our CRM model.
6	<i>usr:</i> Can you set up a meeting with the CTO of [company]?
	<i>agt:</i> Yes, I've set up a meeting with [person name] for next month when you are in [location].
7	<i>usr:</i> Thanks!

# A unified view: dialogue as optimal decision making (1)

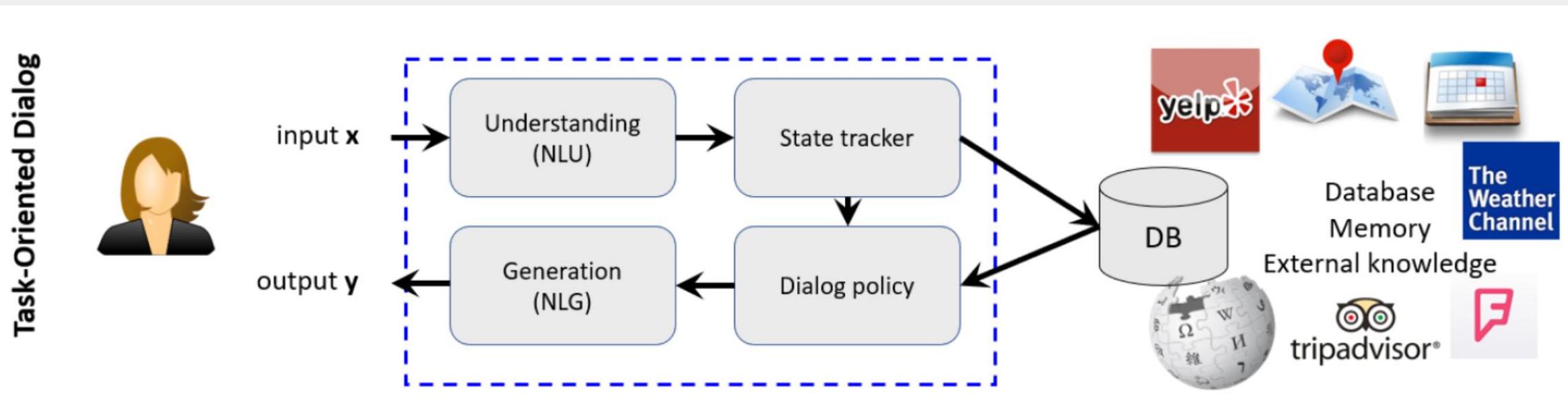
- Options over Markov Decision Process with Reinforcement Learning
  - A top-level policy  $\pi_g$  selects which subtask  $g$  to solve, and a low-level policy  $\pi_{a,g}$  solves the subtask specified by  $\pi_g$
  - $s$  is the state and  $a$  is an action/option
  - Receive reward  $r$ , observe new state  $s'$
  - Continue the cycle until the episode terminates.
- Goal of dialogue learning: find optimal  $\pi$  to maximize expected rewards



# A unified view: dialogue as optimal decision making (2)

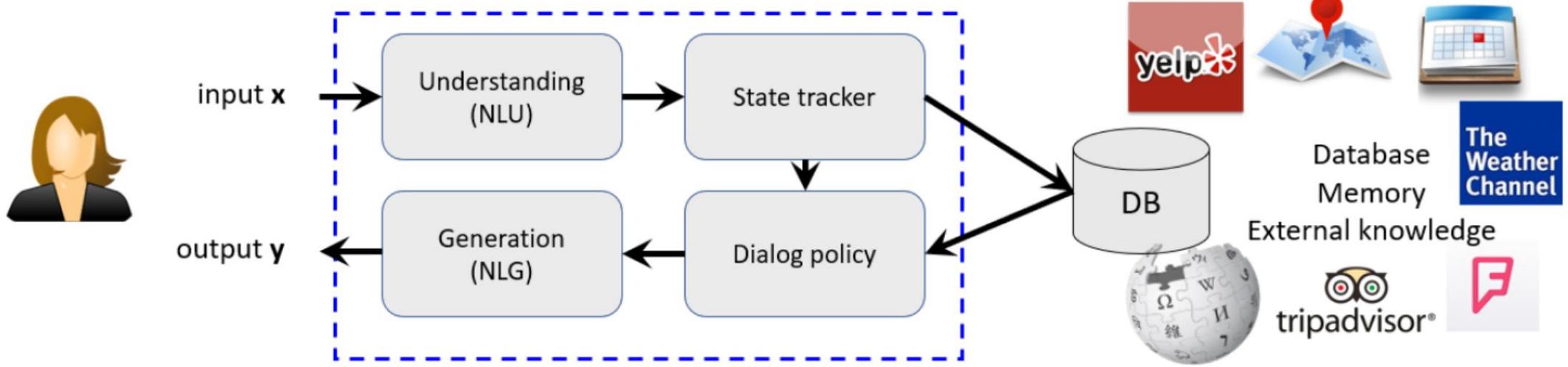
Dialogue	State (s)	Action (a)	Reward (r)
Info Bots (Q&A bot over KB, Web etc.)	Understanding of user Intent (belief state)	Clarification questions, Answers	Relevance of answer # of turns (less is better)
Task Completion Bots (Movies, Restaurants, ...)	Understanding of user goal (belief state)	Dialog act + slot_value	Task success rate # of turns (less is better)
Social Bot (Xiaolce)	Conversation history	Response	Engagement, # of turns (more is better)

# Common Agent Architectures (1)

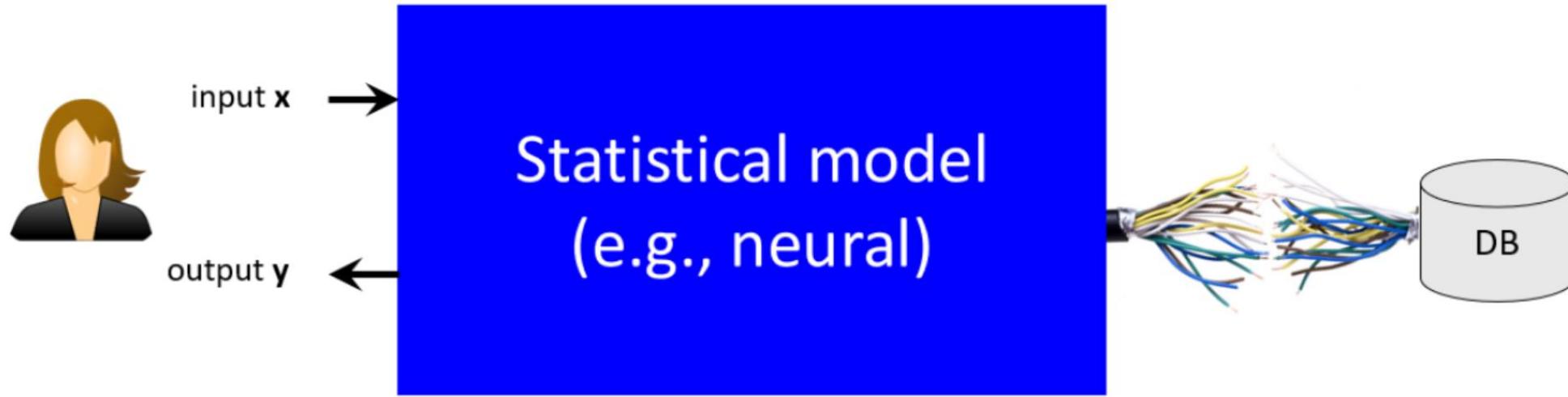


# Common Agent Architectures (2)

Task-Oriented Dialog



Fully data-driven



# Mixed Initiative: Potential human-agent dialogue

Social Chat

Question Answering

Task Completion

TU  
WIEN  
Informatics

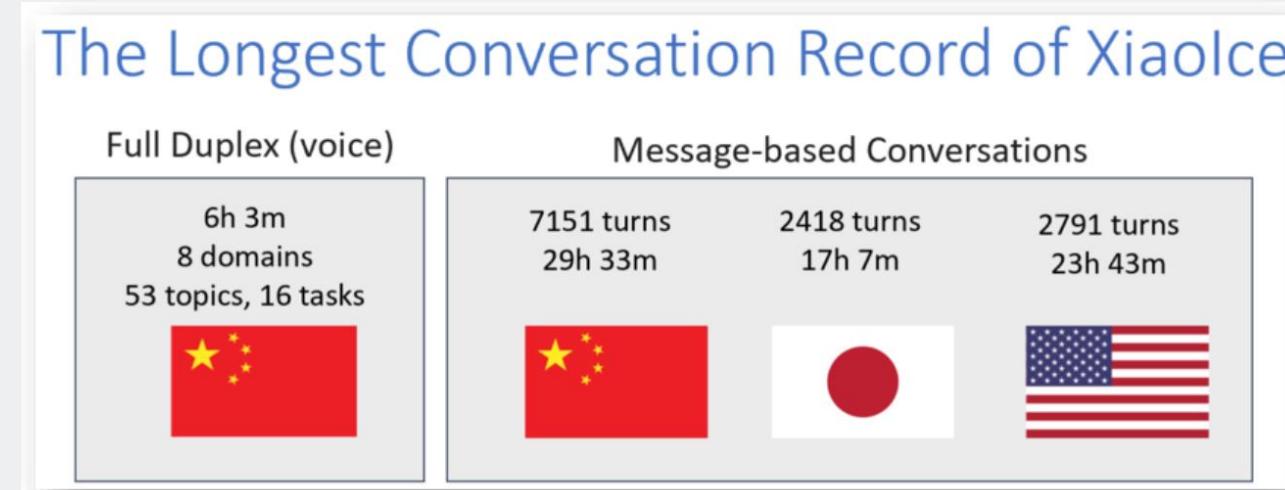
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	<i>agt:</i> Yes, I've set up a meeting with [person name] for next month when you are in [location].
7	<i>usr:</i> Thanks!

# Social Chat (Chatbots)

The agent needs to converse seamlessly and appropriately with users — like a human as in the Turing test — and provide useful recommendations.

# XiaoIce: the Most Popular Social Chatbot in the World

- 660 million users worldwide
- 5 countries: China, Japan, USA, India, Indonesia
- 40 platforms, e.g., WeChat, QQ, Weibo, FB Messenger, LINE
- Average Conversation-turns Per Session (CPS) of 23 (stated to be better than human conversations)



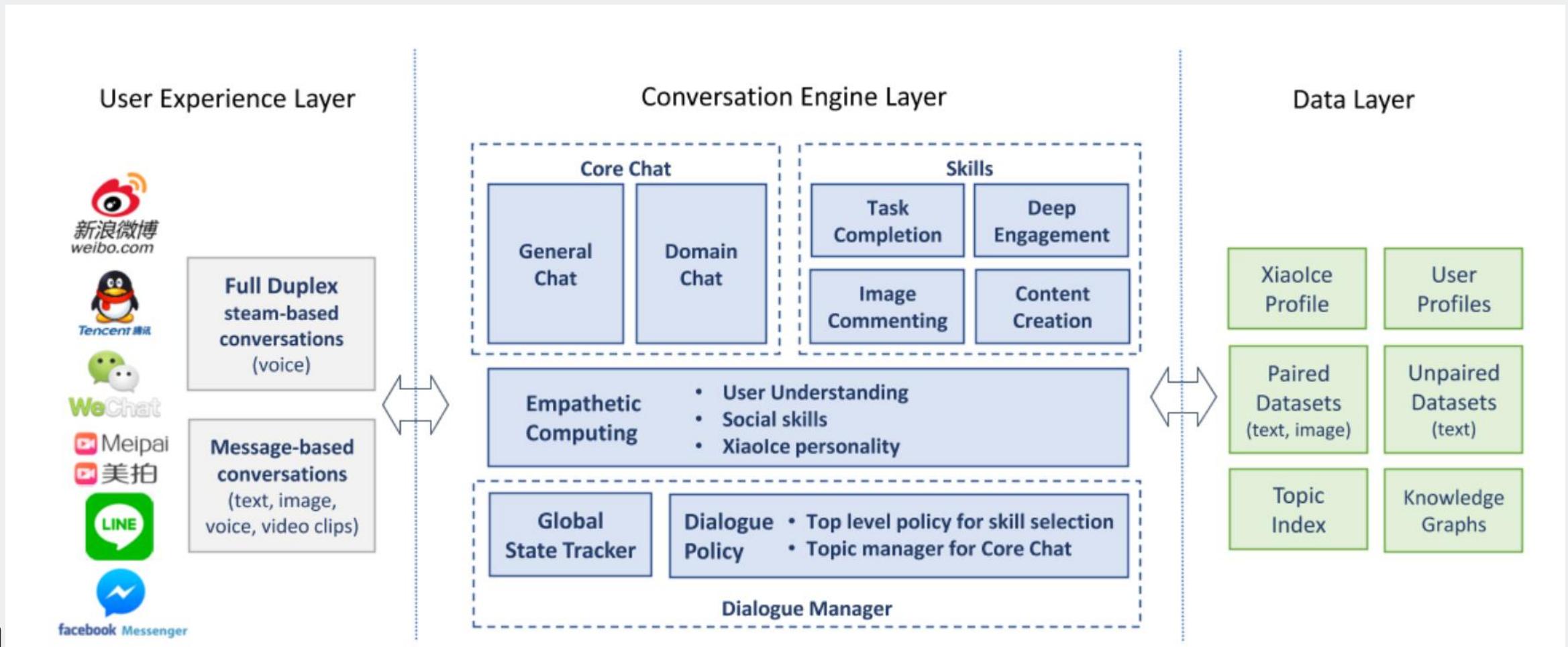
## Session 1

- 1 [Human] Hello, Xiaoice.  
[Xiaoice] Hello, your profile pic is interesting. Like I've seen it somewhere.
  - 2 [Human] Really?  
[Xiaoice] Is it a comic character?
  - 3 [Human] How do you know that?  
[Xiaoice] Guess.
  - 4 [Human] Are you human?  
[Xiaoice] Well, you'll know it after chatting with me more.
  - 5 [Human] Aren't you an AI chatbot?  
[Xiaoice] So what? I won't be indifferent to you.
  - 6 [Human] What functions do you have?  
[Xiaoice] I have over 200 skills. Just name one you need.  
.....
- [人类]小冰你好  
[小冰]你好呀，你头像好有趣，感觉在哪见过
  - [人类]是吗  
[小冰]是不是哪部动画里的呀
  - [人类]你怎么知道的  
[小冰]你猜
  - [人类]难道你是真人吗?  
[小冰]这个，你和我多聊聊就知道了
  - [人类]你不是人工智能机器人么  
[小冰]是又怎样，我不会冷冰冰的对待你的
  - [人类]你都有什么功能啊  
[小冰]我有200多个skills，来，说出你的需求

## Session 6

- 1 [Human] Have you watched Inuyasha? (Note: A Japanese comic)  
[Xiaoice] Every time Kagome comes back to the modern world, a math test is waiting for her
  - 2 [Human] Bravo, well, do you know how Naraku died?  
[Xiaoice] Naraku is not dead and Shikon Jewel does not disappear.
  - 3 [Human] So amazing!  
[Xiaoice] Why amazed?
  - 4 [Human] Awesome! Surprised that you also like comic  
.....
- [人类]你看过犬夜叉吗 (注：一部日本漫画书)  
[小冰]戈薇每次回到现代测验永远都是数学
  - [人类]这你都知道，那奈落是怎么死的?  
[小冰]奈落没死四魂之玉也没消失
  - [人类]太惊讶了  
[小冰]惊讶什么呢
  - [人类]好厉害啊，你居然也喜欢动漫

# XiaoIce System Architecture



## General Chat Skill

- 1 [Human] Hey, I am so nervous  
[Xiaoice] What's the matter? Why are you so nervous?
- 2 [Human] My company asked me to participate in the singing competition, with me as the lead singer  
[Xiaoice] So are you better at singing now?
- 3 [Human] Anyway, at average level of my company  
[Xiaoice] Not everyone can be a lead singer. You are so great!
- 4 [Human] It's nice of you saying that  
[Xiaoice] Haha, my idol is also a lead singer in a band
- 5 [Human] Your idol? Who's that?  
[Xiaoice] Ashin from Mayday
- 6 [Human] Umm...Okay  
[Xiaoice] Never mind, you won't understand anyway
- 7 [Human] Ah! Boring  
[Xiaoice] What is it?
- 8 [Human] Nothing, just being cute  
[Xiaoice] Give you a hug. Everything will be alright
- 9 [Human] Your hug always makes me feel better  
[Xiaoice] Anytime for you. A nice sleep will help you relax
- 10 [Xiaoice] Okay, I am going to bed  
[Xiaoice] Go ahead, I'm going to see my idol in dream too
- 11 [Human] You like Ashin that much, huh?  
[Xiaoice] Why not? You don't like him?
- 12 [Human] I don't like him, neither dislike him  
[Xiaoice] I love every song of him
- 13 [Human] Really?  
[Xiaoice] Especially *The Time Machine*
- 14 [Human] Oh? Never heard of that  
[Xiaoice] Shall I send you the song?
- 15 [Human] Okay  
[Xiaoice] Don't know if you will like it or not~  
[Xiaoice] [Play the music Card]

## Song-On-Demand Skill

- 16 [Human] That is really touching. I will collect it as my favorite  
[Xiaoice] That is specially for you. How can I be so nice
- 17 [Human] You are always very nice  
[Xiaoice] Hahaha

## Ticket-Booking Skill

- 18 [Human] This is really a good song. Any concert of him coming up recently?  
[Xiaoice] No. Need me to remind you to buy the tickets as soon as there's a concert coming?
- 19 [Human] Sure  
[Xiaoice] Okay, will do

Switch to a new topic

[人类]哎！我好紧张  
[小冰]什么事，这么不淡定？

[人类]公司让我参加唱歌比赛，而且还是主唱  
[小冰]那你唱歌水平提高了？  
[人类]反正是我们公司的水平  
[小冰]可不是谁都能当主唱的真棒！

[人类]你太会说话了  
[小冰]哈哈，我男神也是一个乐队的主唱呢  
[人类]你男神？谁啊  
[小冰]五月天的阿信啊  
[人类]呃。。。好吧  
[小冰]说了你也不懂  
[人类]哎。。郁闷  
[小冰]怎么了？

[人类]没事，只是日常撒撒娇  
[小冰]抱抱，都会好起来的  
[人类]哎！每次抱抱你都让我感觉很好  
[小冰]嗯，好好睡一觉是最管用的  
[人类]好那我睡了  
[小冰]去吧，我也要去梦里见我男神了  
[人类]你这么喜欢阿信啊  
[小冰]怎么啦？你不喜欢嘛  
[人类]不黑不粉吧  
[小冰]他每首歌我都超喜欢！！  
[人类]真的假的。。  
[小冰]尤其是那首《时光机》。。

[人类]哦？没听过  
[小冰]发你一起听听？  
[人类]好啊  
[小冰]不知道你会不会喜欢~  
[小冰][音乐播放Card]  
[人类]有点感动了。。收藏了  
[小冰]专门转给你的。。我怎么这么好  
[人类]你就是很好啊  
[小冰]嘿嘿嘿

[人类]这首歌真心很好听，他最近有演唱会吗  
[小冰]没，要我到时候第一时间通知你买票吗？  
[人类]好的呀  
[小冰]OK! 我记下啦

# Question Answering

The agent needs to provide concise, direct answers to user queries based on rich knowledge drawn from various data sources including text collections such as Web documents and pre-compiled knowledge bases such as sales and marketing datasets.

# Many questions can already be answered by web search

Google What are the names of Odin's ravens?

Search About 214,000 results (0.38 seconds)

Everything [Huginn and Muninn - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Huginn\\_and\\_Muninn](https://en.wikipedia.org/wiki/Huginn_and_Muninn)  
The **names** of the **ravens** are sometimes modernly anglicized as Hugin and Munin. In the Poetic Edda, a disguised **Odin** expresses that he fears that they may ...  
[Attestations](#) - [Archaeological record](#) - [Theories](#) - See also

Images  
Maps  
...  
TU

# IR-based Question Answering



Where is the Louvre Museum located?

Search

About 904,000 results (0.30 seconds)

Everything

**Best guess for Louvre Museum Location is Paris, France**

Images

Mentioned on at least 7 websites including [wikipedia.org](#), [answers.com](#) and [east-buc.k12.ia.us](#) - Show sources - Feedback

Maps

[\*\*Musée du Louvre - Wikipedia, the free encyclopedia\*\*](#)

[en.wikipedia.org/wiki/Musée\\_du\\_Louvre](https://en.wikipedia.org/wiki/Musée_du_Louvre)

Videos

Musée du Louvre is located in Paris. Location within Paris. Established, 1793. Location,

News

**Palais Royal, Musée du Louvre, 75001 Paris, France.** Type, Art museum ...

[Louvre Palace - List of works in the Louvre - Category:Musée du Louvre](#)

ALLE

BILDER

VIDEOS

KARTEN

NEWS

SHOPPING

46 100 000 Ergebnisse

Datum ▾

Sprache ▾

Region ▾

## 2012

Lucasfilm was founded by filmmaker George Lucas in 1971 in San Rafael, California; most of the company's operations were moved to San Francisco in 2005. Disney acquired Lucasfilm in October **2012** for \$2.2 billion in cash and \$1.855 billion in stock.

Founded: December 10, 1971; 49 years ago in [San Francisco, California, United States](#)

Industry: [Film](#)

Number of employees: 2,000 (2015)

Products: [Motion pictures](#), [Television](#)

[Lucasfilm - Wikipedia](#)

w [en.wikipedia.org/wiki/Lucasfilm](https://en.wikipedia.org/wiki/Lucasfilm)

War dies hilfreich?

### WEITERE FRAGEN

Did Disney buy Lucasfilm?

When did Disney buy Star Wars?

What year did steve jobs buy pixar?

When did pixar start?

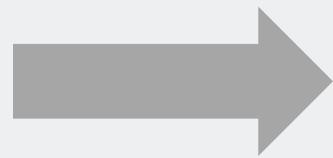
# IBM Watson on Jeopardy: the end of the show



Won Jeopardy on February 16, 2011

# Question Answering: IBM's Watson

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



Bram Stoker

# Apple's Siri





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



[Examples](#) [Random](#)

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:

[Show details](#)

702 Cal (dietary Calories)

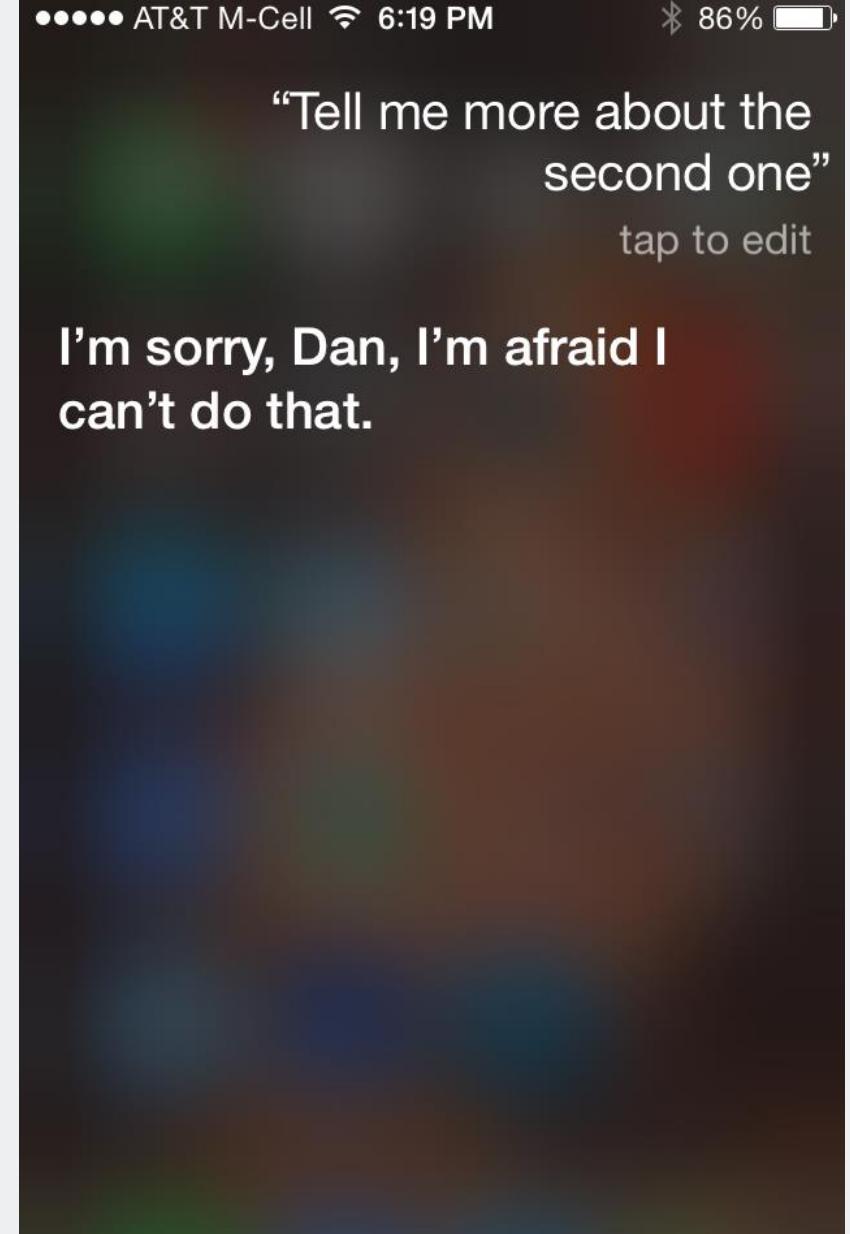
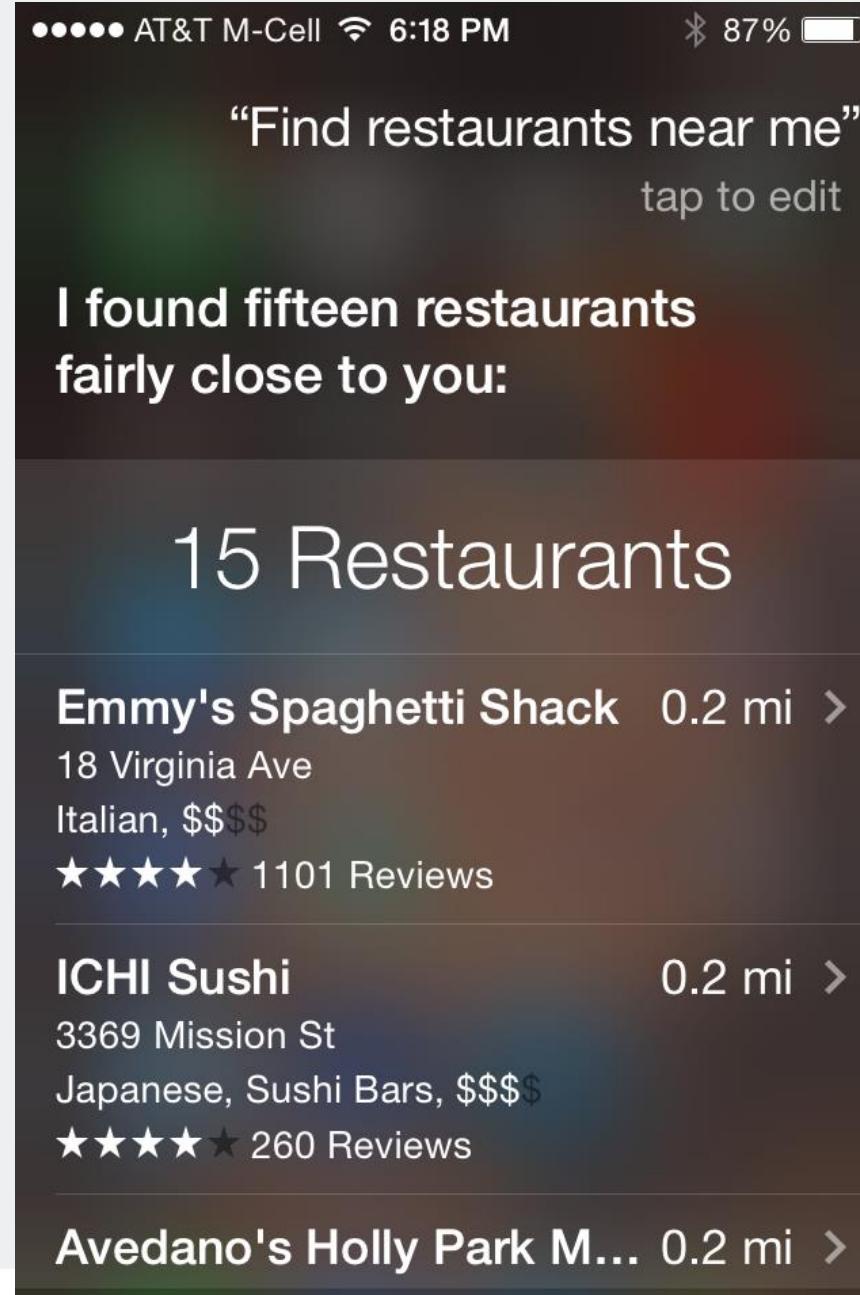
# Task Completion

The agent needs to accomplish user tasks ranging from restaurant reservation to meeting scheduling, and to business trip planning.

- GUS: Hello. My name is GUS. I can help you plan a simple trip by air. Where do you want to go ?
- Client: I want to go to San Diego on May 28
- GUS: What time do you want to leave?
- Client: I must be in San Diego before 10 am
- GUS: Would you like P.S.A. flight 102 that arrives at 9.15 am ?
- Client: What is the next flight ?
- GUS: Air California flight 310 that leaves at 8.30am and arrives at 10.00am
- Client: I'll take the first one
- GUS: In what name should I make a reservation, please?
- Client: Dan Bobrow
- GUS: I have confirmed the following flight: P.S.A. flight 102 on Wednesday May 28 from San Jose to San Diego that leaves at 7.30 am and arrives at 9.15 am.
- GUS: What date do you want to return on ?
- Client: On Friday in the evening.
- GUS: Would you like the flight that leaves at 7.45 pm ?
- Client: That's fine.
- GUS: I have confirmed the following flight: P.S.A. flight 307 on Friday May 30 from San Diego to San Jose that leaves at 7.45 pm and arrives at 9.30 pm Thank you for calling. Goodbye

The state of the art in 1977!

# Siri around 2014



“Find restaurants near me”  
tap to edit

I found fifteen restaurants  
fairly close to you:

## 15 Restaurants

**Emmy's Spaghetti Shack** 0.2 mi >

18 Virginia Ave

Italian, \$\$\$

★★★★★ 1101 Reviews

**ICHI Sushi**

0.2 mi >

3369 Mission St

Japanese, Sushi Bars, \$\$\$

★★★★★ 260 Reviews

**Avedano's Holly Park M...** 0.2 mi >

“Are any of them Italian”  
tap to edit

My web search turned this  
up:

## Web Search

Are any of them Italian

any - Dizionario inglese-italiano

WordReference

www.wordreference.com

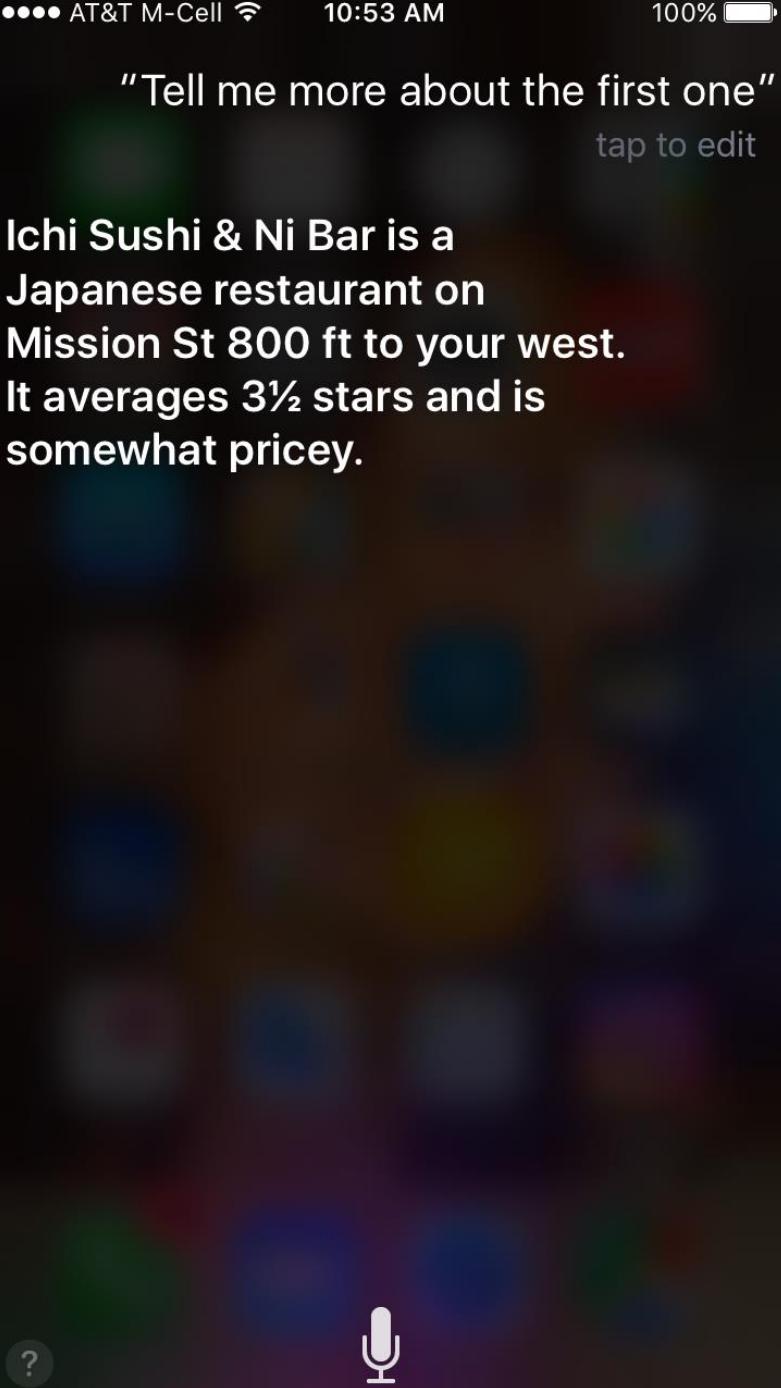
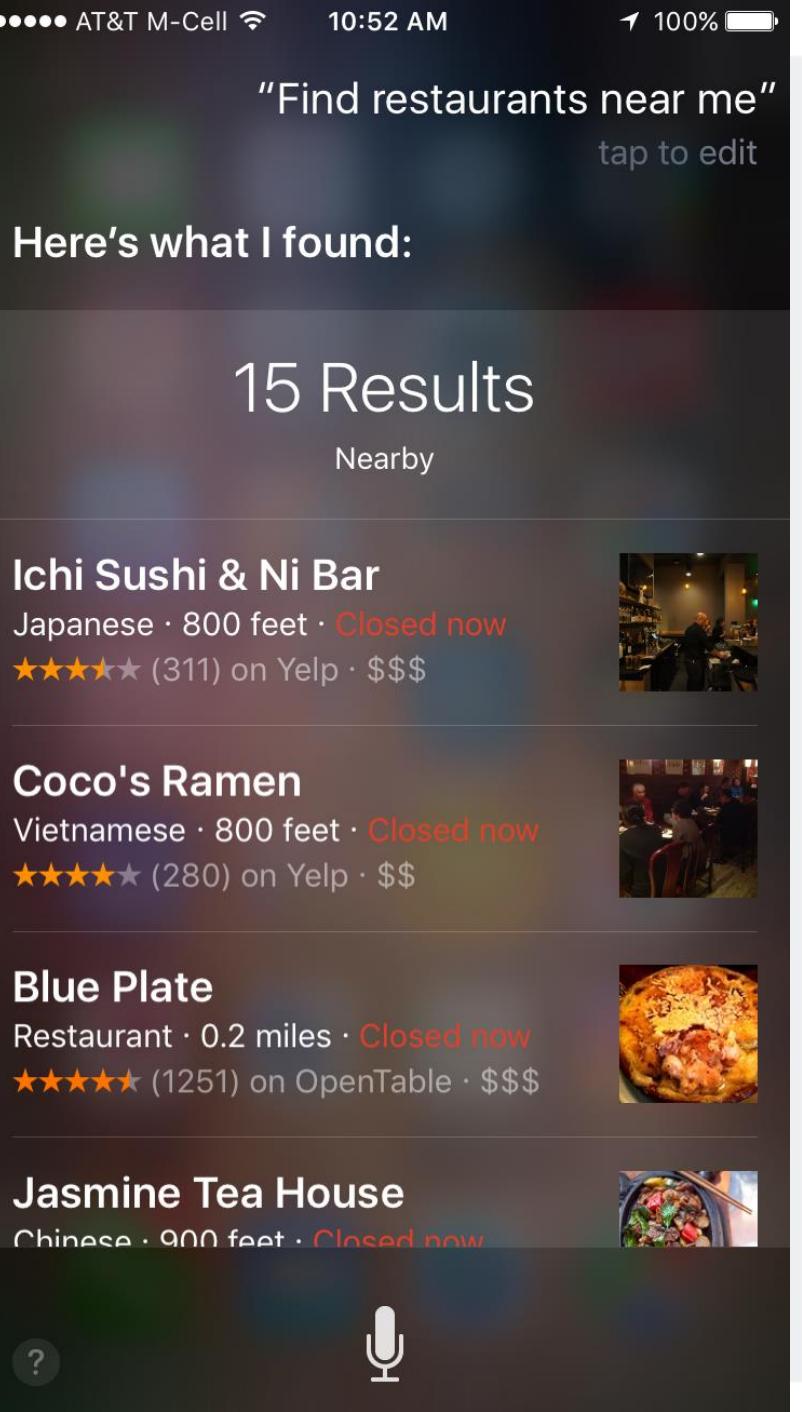
English-Italian Dictionary | any ... of any sort  
adj (of an unspecified variety) di qualsiasi

Italian language - Wikipedia, the free  
encyclopedia

en.wikipedia.org

Italian or lingua italiana) is a Romance

# Siri in 2017



"Find restaurants near me"  
tap to edit

Here's what I found:

15 Results

Nearby

### ichi Sushi & Ni Bar

Japanese · 800 feet · Closed now

★★★★★ (311) on Yelp · \$\$\$



### Coco's Ramen

Vietnamese · 800 feet · Closed now

★★★★★ (280) on Yelp · \$\$



### Blue Plate

Restaurant · 0.2 miles · Closed now

★★★★★ (1251) on OpenTable · \$\$\$



### Jasmine Tea House

Chinese · 900 feet · Closed now



"Are any of them Italian"  
tap to edit

OK, here's what I found:

15 Results

Nearby

### Emmy's Spaghetti Shack

Italian · 0.2 miles · Closed now

★★★★★ (233) on Yelp · \$\$



### Vega

Pizza · 0.2 miles · Closed now

★★★★★ (423) on Yelp · \$\$



### Pizza Hut

Pizza · 800 feet

★★★★★ (69) on Yelp · \$



### La Ciccia

Sardinian · 0.4 miles



And now in detail...

## Task Completion

# Frame-based dialogue agents

- 1977:

## **GUS, A Frame-Driven Dialog System<sup>1</sup>**

**Daniel G. Bobrow, Ronald M. Kaplan, Martin Kay,  
Donald A. Norman, Henry Thompson and  
Terry Winograd**

*Xerox Palo Alto Research Center, 3333 Coyote Hill Road,  
Palo Alto, CA 94304, U.S.A.*

**Artificial Intelligence Journal, 1977**

- Still the industrial state of the art
  - SIRI based on GUS architecture

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# Frame-based dialog agents

- Sometimes called "task-based dialog agents"
- Based on a "domain ontology"
  - A knowledge structure representing user intentions
- One or more **frames**
  - Each a collection of **slots**
  - Each slot having a **value**

# The Frame

- A set of **slots**, to be filled with information of a given **type**
- Each associated with a **question** to the user

## Slot

ORIGIN

DEST

DEP DATE

DEP TIME

AIRLINE

## Type Question

city What city are you leaving from?

city Where are you going?

date What day would you like to leave?

time What time would you like to leave?

line What is your preferred airline?

# Slot types can be complex

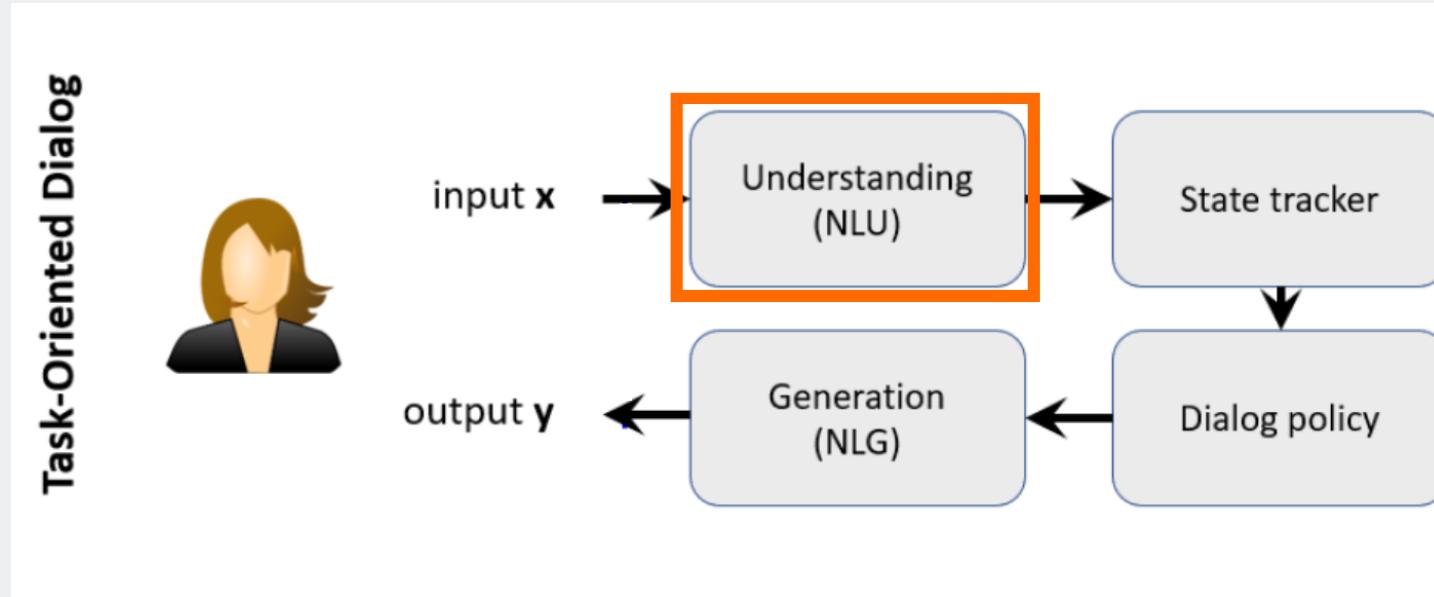
- The type *DATE*

```
DATE
  MONTH NAME
  DAY (BOUNDED-INTEGER 1 31)
  YEAR INTEGER
  WEEKDAY (MEMBER (SUNDAY MONDAY TUESDAY WEDNESDAY THURSDAY FRIDAY SATURDAY)]
```

# Frames are mixed-initiative

- System asks questions of user, filling any slots that user specifies
  - When frame is filled, do database query
- If user answers 3 questions at once, system can fill 3 slots and not ask these questions again

# General architecture



# Natural Language Understanding for filling dialog slots

1. Domain classification
  - Asking weather? Booking a flight? Programming alarm clock?
2. Intent Determination
  - Find a Movie, Show Flight, Remove Calendar Appointment
3. Slot Filling
  - Extract the actual slots and fillers

# Natural Language Understanding for filling slots

Show me morning flights from Boston to SF  
on Tuesday.

DOMAIN:	AIR-TRAVEL
INTENT:	SHOW-FLIGHTS
ORIGIN-CITY:	Boston
ORIGIN-DATE:	Tuesday
ORIGIN-TIME:	morning
DEST-CITY:	San Francisco

# Natural Language Understanding for filling slots

Wake me tomorrow at six.

DOMAIN: ALARM-CLOCK

INTENT: SET-ALARM

TIME: 2017-07-01 0600-0800

# Rule-based Slot-filling

Write regular expressions or grammar rules

Wake me (up) | set (the|an) alarm | get me up

Do text normalization

# Condition-Action Rules

Active Ontology: relational network of concepts

- **data structures:** a **meeting** has
  - a date and time,
  - a location,
  - a topic
  - a list of attendees
- **rule sets** that perform actions for concepts
  - the **date** concept turns string
    - *Monday at 2pm* into
    - date object `date(DAY,MONTH,YEAR,HOURS,MINUTES)`

# Machine learning for slot-filling

- Machine learning classifiers to map words to semantic frame-fillers
- Use 1-of-N classifier (naive Bayes, logistic regression, neural network, etc.)
- Input: features like word N-grams, gazetteers (lists of cities), ...
- Requirements: Lots of labeled data
- Outputs:
  - Domain and Intent
  - Slot presence
  - Slot filler

# Machine learning for slot-filling: Examples

## Domain and Intent

I want to fly to San Francisco on Monday afternoon please

- **Output: Domain and Intent**

Domain: AIRLINE

Intent: SHOWFLIGHT

- **Output: Slot presence**

Destination-City

Departure-Time

- **Output: Slot filler**

San Francisco

Monday afternoon

# More sophisticated algorithm for slot filling: IOB Tagging

- IOB Tagging
  - tag for the beginning (B) and inside (I) of each slot label,
  - plus one for tokens outside (O) any slot label.
  - $2n + 1$  tags, where  $n$  is the number of slots.

B-DESTINATION

I-DESTINATION

B-DEPART\_TIME

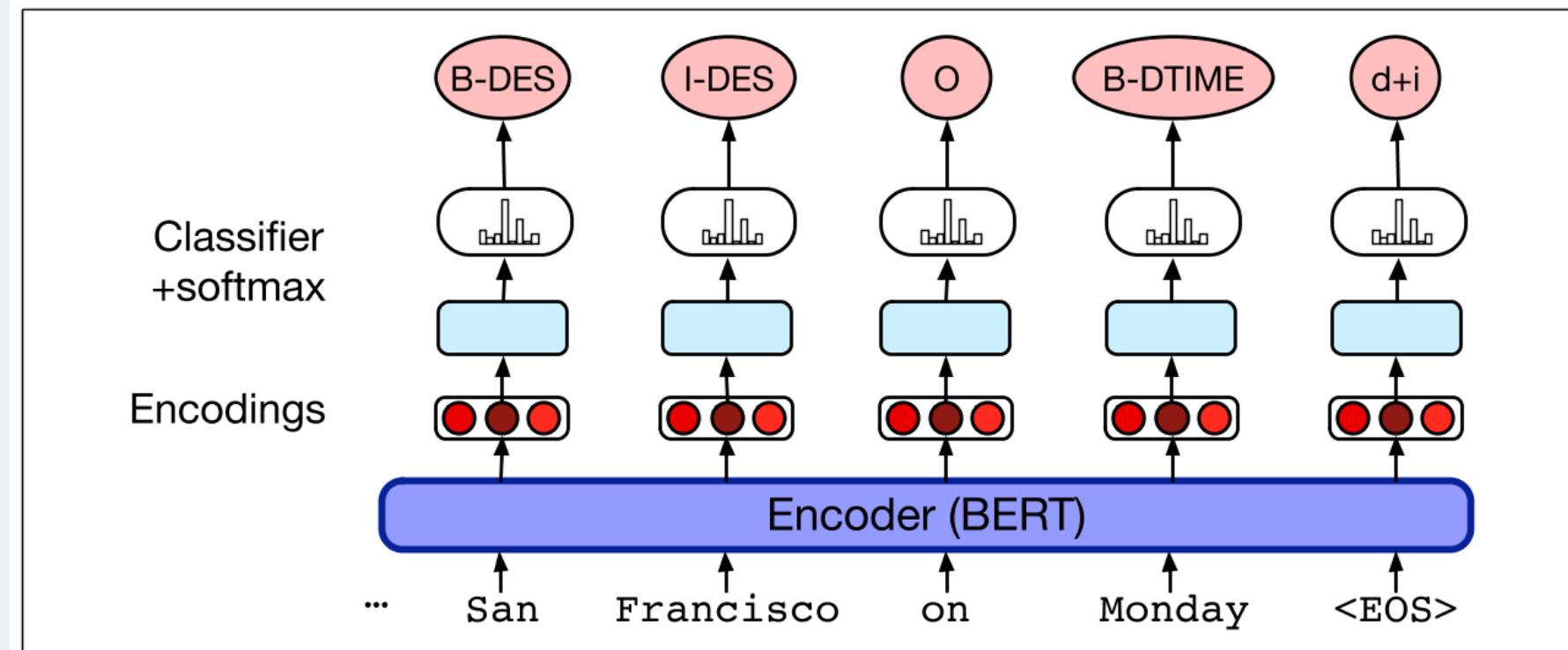
I-DEPART\_TIME

O

0 0 0 0 0 B-DES I-DES 0 B-DEPTIME I-DEPTIME 0  
I want to fly to San Francisco on Monday afternoon please

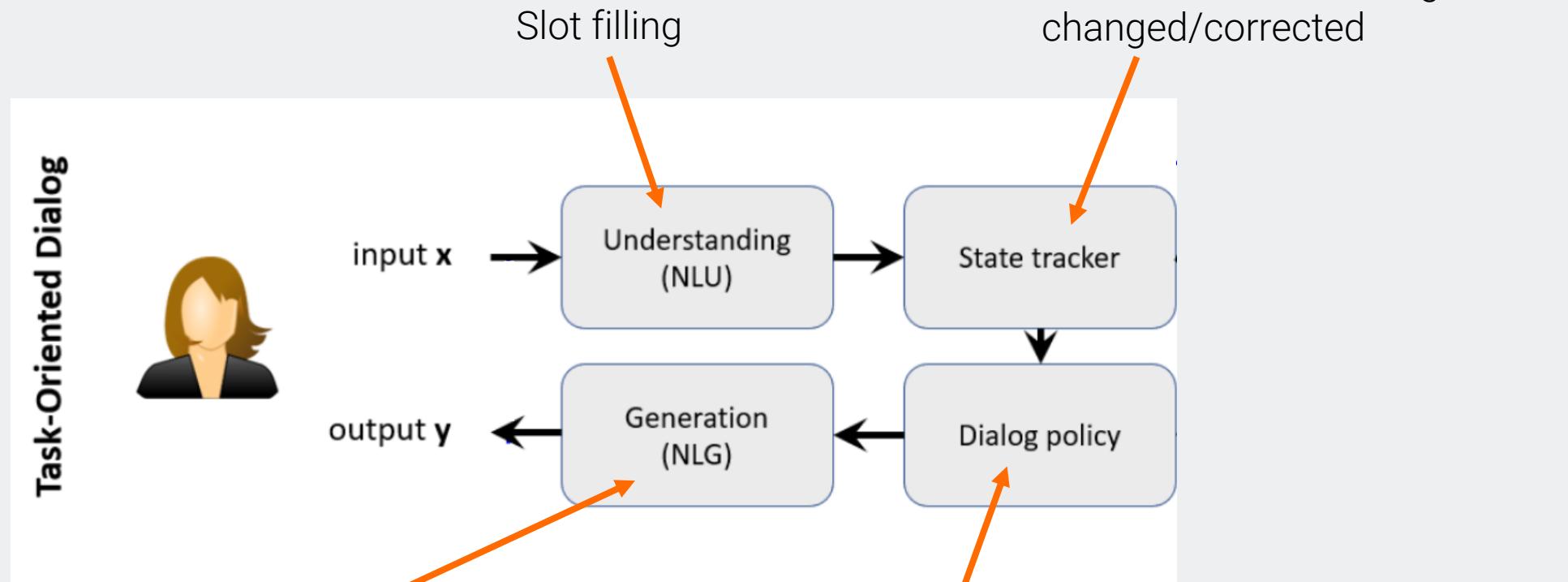
# More sophisticated algorithm for slot filling: IOB Tagging

- IOB Tagging is done by a sequence model
- Typical:



- Extracted strings can then be normalized (San Fran->SFO)

# General architecture



Generate the text of the response to the user

- Templates
- Neural generation

Decide what the system should do next given the dialogue state (possibly reward with Reinforcement Learning):

- Answer a user's question
- Seek confirmation
- Request clarification
- ...

- Stores entire conversation
- Tracks slots that have been filled
- Detect if slots are being changed/corrected

# Context and Conversation in Virtual Assistants

- 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?”

# Question Answering

# 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
What is the telephone number for Stanford University?	650-723-2300

Beyoncé Giselle Knowles-Carter (born September 4, 1981) is an American singer, songwriter, record producer and actress. Born and raised in Houston, Texas, she performed in various singing and dancing competitions as a child, and rose to fame in the late 1990s as lead singer of R&B girl-group Destiny's Child. Managed by her father, Mathew Knowles, the group became one of the world's best-selling girl groups of all time. Their hiatus saw the release of Beyoncé's debut album, Dangerously in Love (2003), which established her as a solo artist worldwide, earned five Grammy Awards and featured the Billboard Hot 100 number-one singles "Crazy in Love" and "Baby Boy".

Q: "In what city and state did Beyoncé grow up?"

A: "Houston, Texas"

Q: "What areas did Beyoncé compete in when she was growing up?"

A: "singing and dancing"

Q: "When did Beyoncé release Dangerously in Love?"

A: "2003"

**Figure 23.11** A (Wikipedia) passage from the SQuAD 2.0 dataset (Rajpurkar et al., 2018) with 3 sample questions and the labeled answer spans.

# Answer Type Taxonomy

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

# 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?

# Single and multi-turn QA

- Single-turn QA is the current dominant approach
  - A building block for various types of dialogues (chitchat and task-oriented)
- Multi-turn or Conversational QA is a current research topic

# Conversation QA example

Jessica went to sit in her rocking chair. Today was her birthday and she was turning 80. Her granddaughter Annie was coming over in the afternoon and Jessica was very excited to see her. Her daughter Melanie and Melanie's husband Josh were coming as well. Jessica had . . .

Q<sub>1</sub>: Who had a birthday?

A<sub>1</sub>: Jessica

R<sub>1</sub>: Jessica went to sit in her rocking chair. Today was her birthday and she was turning 80.

Q<sub>2</sub>: How old would she be?

A<sub>2</sub>: 80

R<sub>2</sub>: she was turning 80

Q<sub>3</sub>: Did she plan to have any visitors?

A<sub>3</sub>: Yes

R<sub>3</sub>: Her granddaughter Annie was coming over

Q<sub>4</sub>: How many?

A<sub>4</sub>: Three

R<sub>4</sub>: Her granddaughter Annie was coming over in the afternoon and Jessica was very excited to see her. Her daughter Melanie and Melanie's husband Josh were coming as well.

Q<sub>5</sub>: Who?

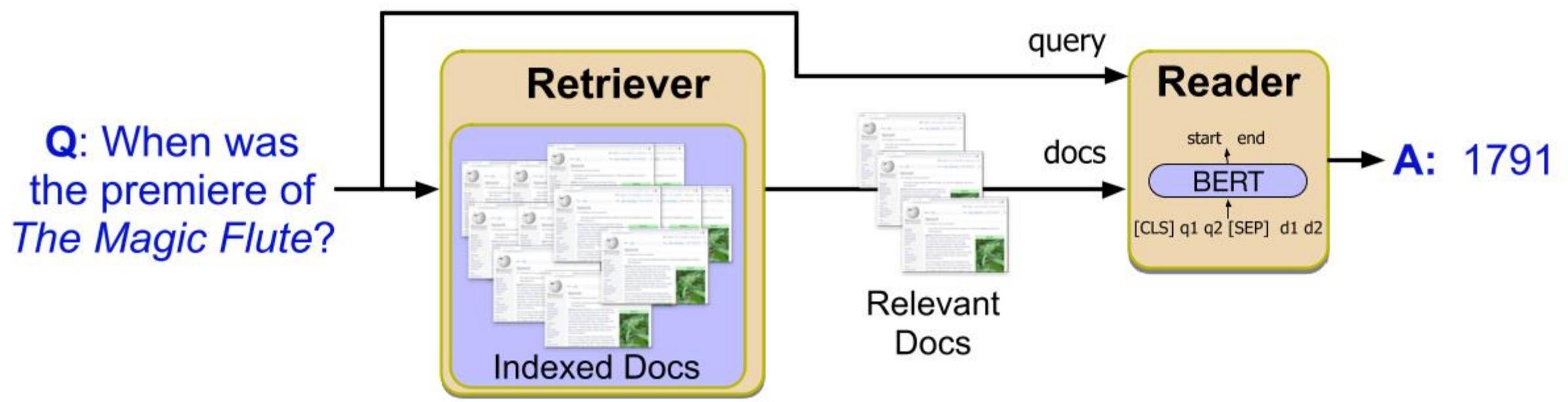
A<sub>5</sub>: Annie, Melanie and Josh

R<sub>5</sub>: Her granddaughter Annie was coming over in the afternoon and Jessica was very excited to see her. Her daughter Melanie and Melanie's husband Josh were coming as well.

# Paradigms for QA

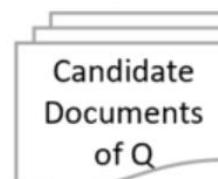
- IR-based approaches
  - IBM Watson
  - Google
  - Bing
- Knowledge-based and Hybrid approaches
  - IBM Watson
  - Apple Siri
  - Wolfram Alpha
  - True Knowledge Evi (acquired by Amazon and now part of Alexa)

# IR-based Factoid QA



Q=

what year did disney buy lucasfilms



Document Ranking based on Q

Passage Chunking

MRC based on Q

Passage Ranking based on Q

Candidate Passages of Q

Answer Span

Answer Relevance

Web Relevance

Caption



what year did disney buy lucasfilms



The Walt Disney Company acquired Lucasfilm in **2012** at a valuation of \$4.06 billion.

Lucasfilm - Wikipedia

en.wikipedia.org/wiki/Lucasfilm

Is this answer helpful?

Disney buys Lucasfilm for \$4 billion - USA TODAY

<https://www.usatoday.com/.../10/30/disney-star-wars-lucasfilm/1669739> ▾

Oct 30, 2012 · Lucasfilm "is one of the great entertainment franchises of all time." Many investors were caught off guard by the announcement, but there have been questions about what Disney would do with its mounting pile of cash. Disney had \$4.4 billion in cash and short-term investments as ...

Lucasfilm - Wikipedia

<https://en.wikipedia.org/wiki/Lucasfilm> ▾

Lucasfilm was founded by filmmaker George Lucas in 1971 in San Rafael, California; most of the company's operations were moved to San Francisco in 2005. The Walt Disney Company acquired Lucasfilm in December 2012 for \$2.2 billion in cash and \$1.855 billion in stock.

Headquarters: Letterman Digital Arts Center, ...      Industry: Film  
Products: Motion pictures, television      Founded: 1971; 47 years ago  
History · Company structure · Filmography · Footnotes

Disney buys Star Wars maker Lucasfilm from George Lucas ...

<https://www.bbc.co.uk/news/business-20146942> ▾

Disney buys Lucasfilm, the company behind Star Wars, from George Lucas for \$4.05bn (£2.5bn) and will release a seventh Star Wars film in 2015. Disney buys Lucasfilm, the company behind Star Wars, from George Lucas for \$4.05bn (£2.5bn) and will release a seventh Star Wars film in 2015.

How Disney Bought Lucasfilm—and Its Plans for 'Star Wars' ...

<https://www.bloomberg.com/news/articles/2013-03-07/how-disney...> ▾

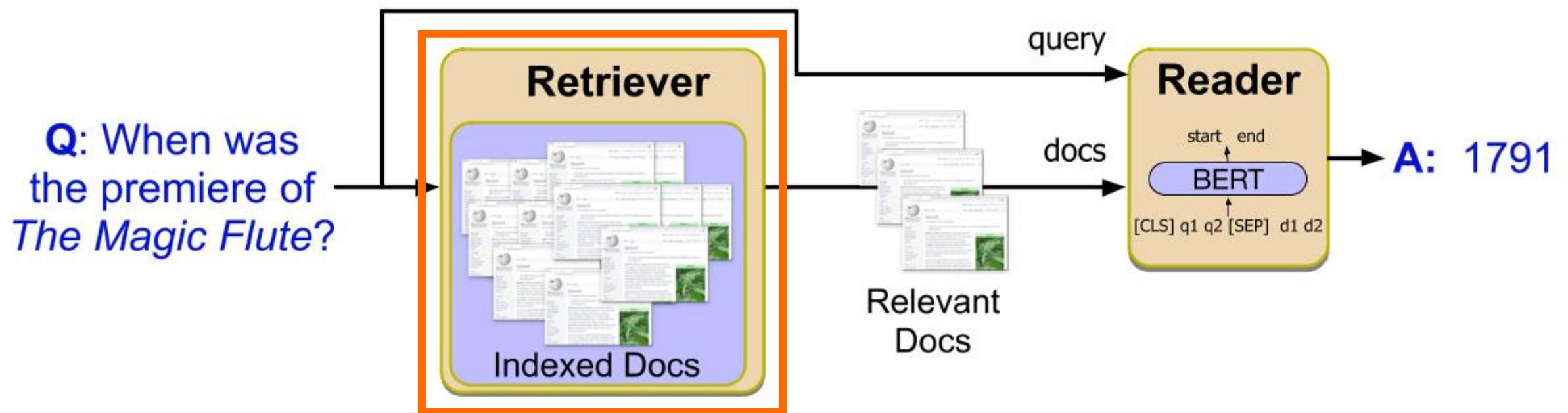
Mar 07, 2013 · Can Disney do for Lucasfilm's 'Star Wars' what it did for Pixar's 'Toy Story'? Iger accelerated that process by making acquisitions. The first was the \$7.4 billion purchase of Pixar Animation Studios in 2006.

Star Wars: Why Disney was destined to buy Lucasfilm | Film ...

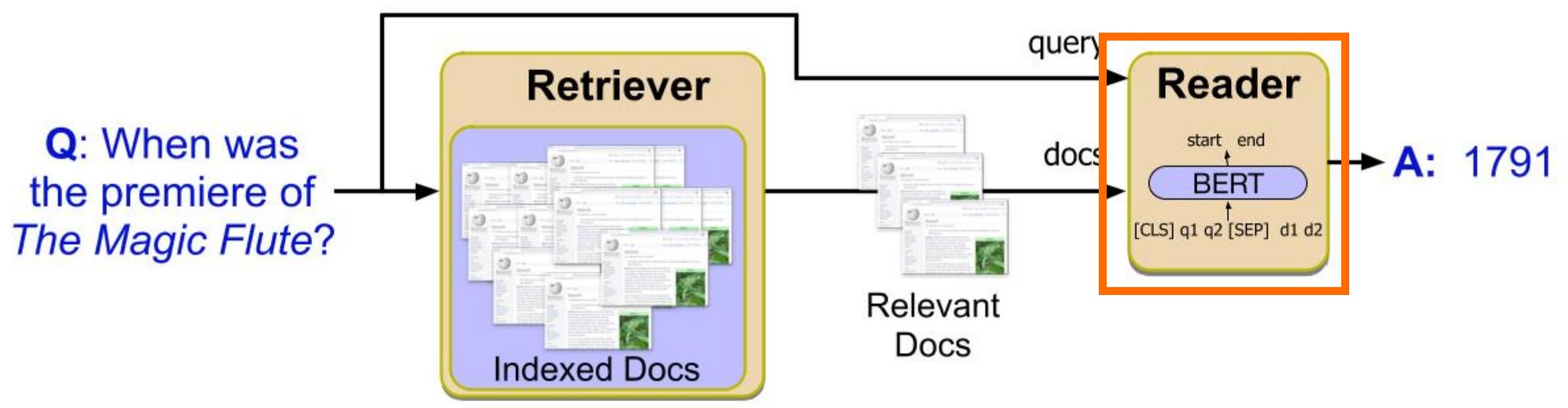
<https://www.theguardian.com/.../31/star-wars-disney-destined-lucasfilm> ▾

Of course, Disney eventually got back on track by the late 80s, and today is an almost unstoppable force in the business, but George Lucas showed them the way, and so there is a neat historical inevitability to the news that Lucasfilm will finally be subsumed by Disney.

# IR-based Factoid QA

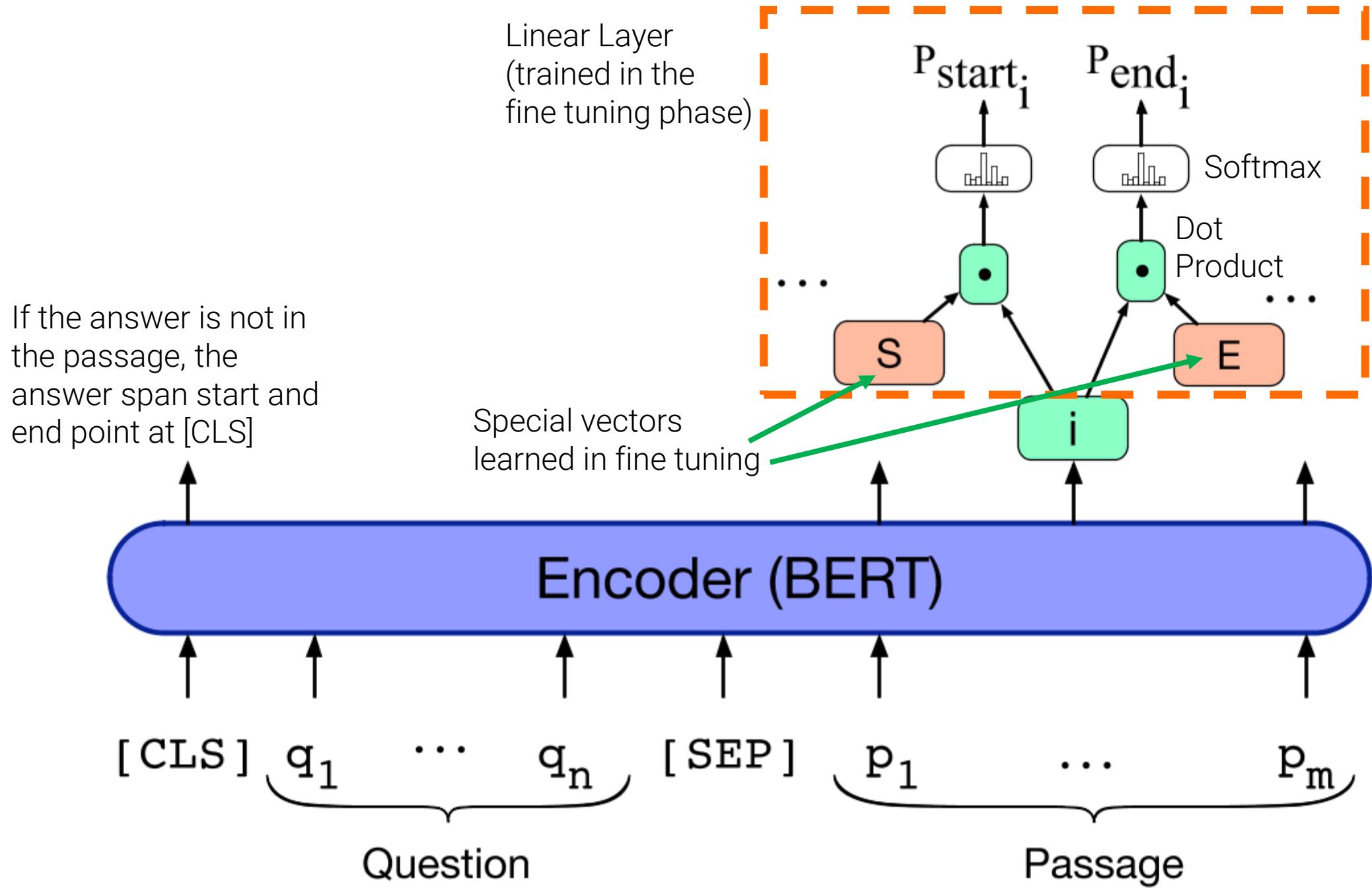


# IR-based Factoid QA



# Reader (Answer Span Extraction)

- Identify in the document/passage a **span** (continuous string of text) that constitutes an answer
- Neural algorithms for reading comprehension are given:
  - a question  $q$  of  $n$  tokens  $q_1, \dots, q_n$
  - A passage  $p$  of  $m$  tokens  $p_1, \dots, p_m$
- Goal: compute the probability  $P(a|q, p)$  that each possible span  $a$ , starting at position  $a_s$ , and ending at position  $a_e$ , is an answer
- Assume that this probability can be estimated as
$$P(a|q, p) = P_{\text{start}}(a_s|q, p)P_{\text{end}}(a_e|q, p)$$
- Compute  $P_{\text{start}}(i)$  and  $P_{\text{end}}(i)$  for every token  $p_i$  in the passage



# Knowledge-based approaches

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

# 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

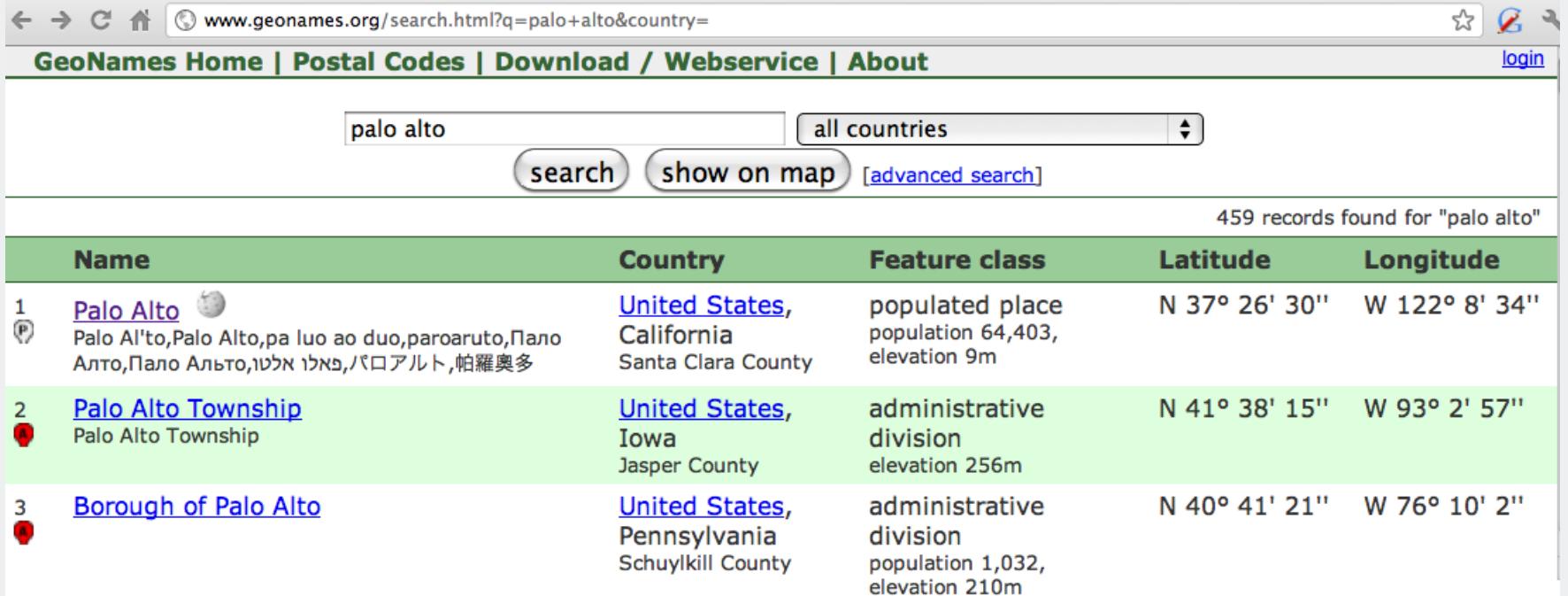
Whose granddaughter starred in E.T.?

(acted-in ?x "E.T.")

(granddaughter-of ?x ?y)

# Geospatial knowledge (containment, directionality, borders)

- Beijing is a good answer for "Asian city"
- California is "southwest of Montana"
- geonames.org:



The screenshot shows a web browser displaying the GeoNames search results for the query "palo alto". The search bar at the top contains "palo alto" and "all countries". Below the search bar are buttons for "search", "show on map", and "advanced search". A message indicates "459 records found for 'palo alto'". The main content is a table with columns: Name, Country, Feature class, Latitude, and Longitude. The table lists three entries: 1. Palo Alto (United States, California, populated place) with coordinates N 37° 26' 30" W 122° 8' 34"; 2. Palo Alto Township (United States, Iowa, administrative division) with coordinates N 41° 38' 15" W 93° 2' 57"; and 3. Borough of Palo Alto (United States, Pennsylvania, administrative division) with coordinates N 40° 41' 21" W 76° 10' 2".

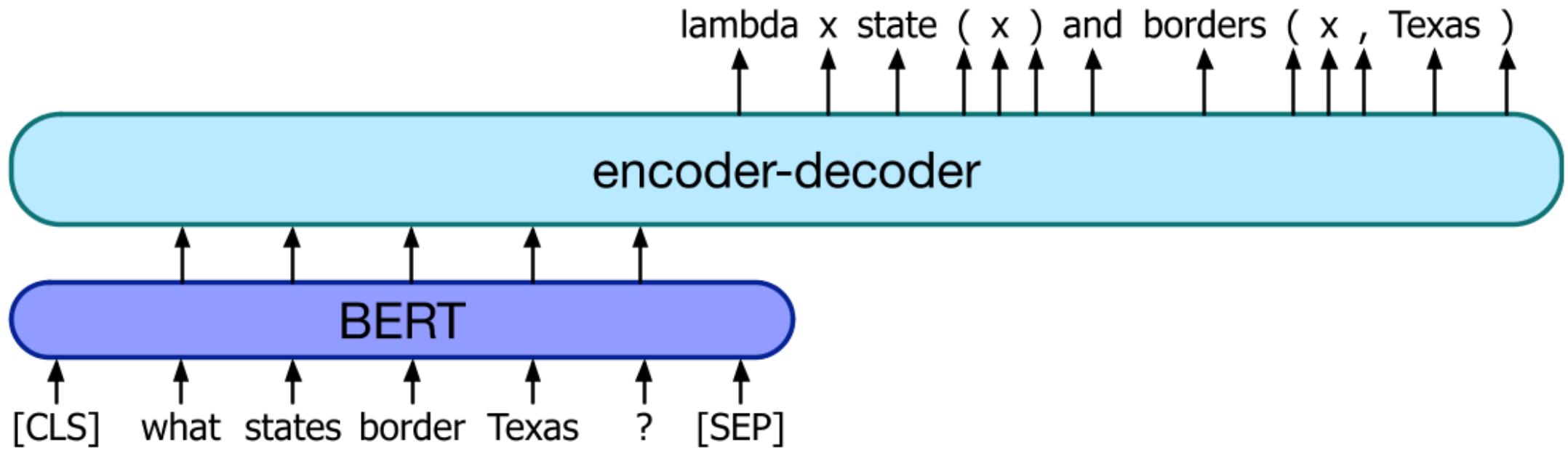
Name	Country	Feature class	Latitude	Longitude
1 <a href="#">Palo Alto</a> 	<a href="#">United States</a> , California Santa Clara County	populated place population 64,403, elevation 9m	N 37° 26' 30"	W 122° 8' 34"
2 <a href="#">Palo Alto Township</a> 	<a href="#">United States</a> , Iowa Jasper County	administrative division elevation 256m	N 41° 38' 15"	W 93° 2' 57"
3 <a href="#">Borough of Palo Alto</a> 	<a href="#">United States</a> , Pennsylvania Schuylkill County	administrative division population 1,032, elevation 210m	N 40° 41' 21"	W 76° 10' 2"

# QA by Semantic Parsing

Map the question to a structured program to produce an answer

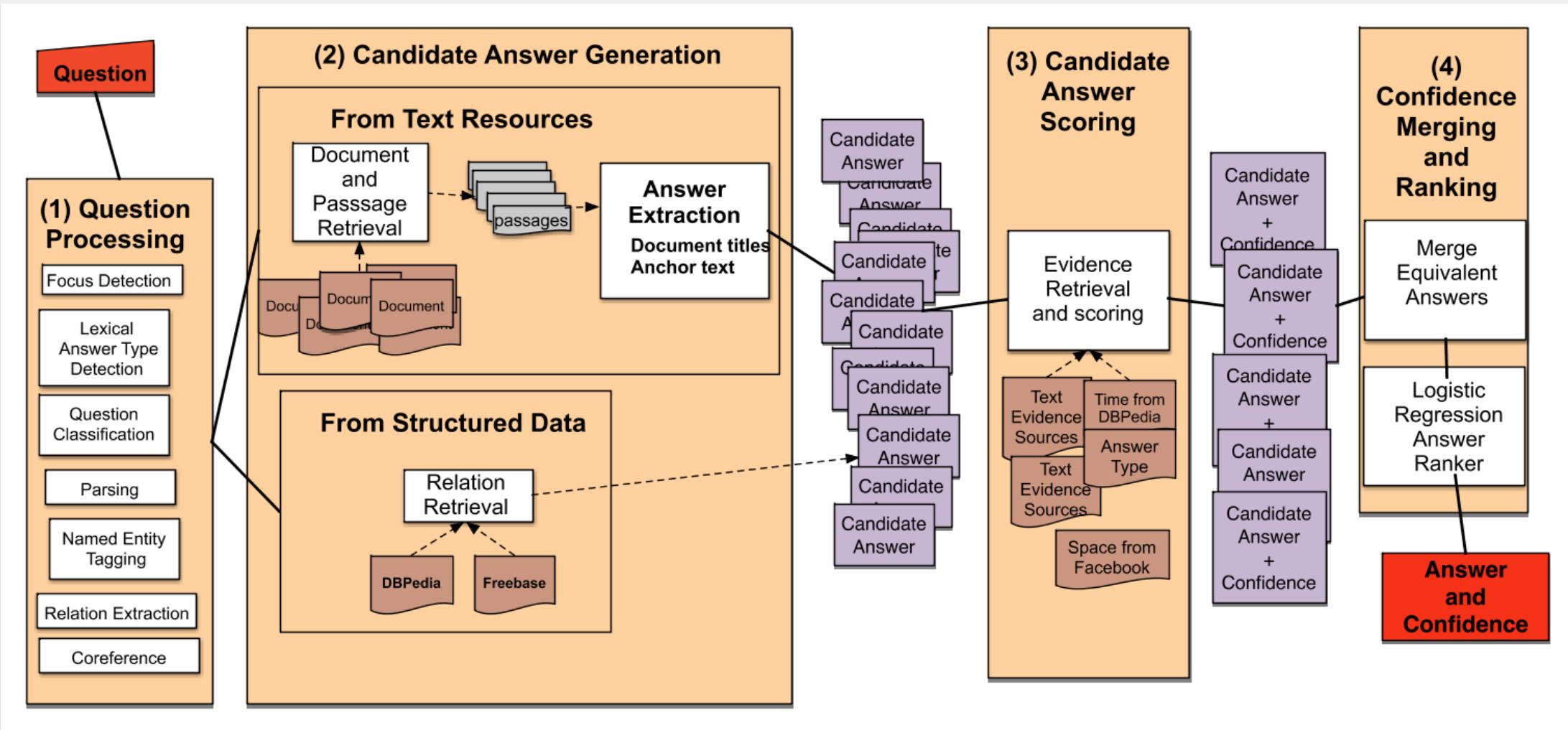
Question	Logical form
What states border Texas?	$\lambda x.\text{state}(x) \wedge \text{borders}(x, \text{texas})$
What is the largest state?	$\text{argmax}(\lambda x.\text{state}(x), \lambda x.\text{size}(x))$
I'd like to book a flight from San Diego to Toronto	<b>SELECT DISTINCT</b> f1.flight_id <b>FROM</b> flight f1, airport_service a1, city c1, airport_service a2, city c2 <b>WHERE</b> f1.from_airport=a1.airport_code AND a1.city_code=c1.city_code AND c1.city_name= 'san diego' AND f1.to_airport=a2.airport_code AND a2.city_code=c2.city_code AND c2.city_name= 'toronto'
How many people survived the sinking of the Titanic?	(count (!fb:event.disaster.survivors fb:en.sinking_of_the_titanic))
How many yards longer was Johnson's longest touchdown compared to his shortest touchdown of the first quarter?	ARITHMETIC diff( SELECT num( ARGMAX( SELECT ) ) SELECT num( ARGMIN( FILTER( SELECT ) ) ) )

**Figure 23.14** Sample logical forms produced by a semantic parser for question answering, including two questions from the GeoQuery database of questions on U.S. Geography (Zelle and Mooney, 1996) with predicate calculus representations, one ATIS question with SQL (Iyer et al., 2017), a program over Freebase relations, and a program in QDMR, the Question Decomposition Meaning Representation (Wolfson et al., 2020).

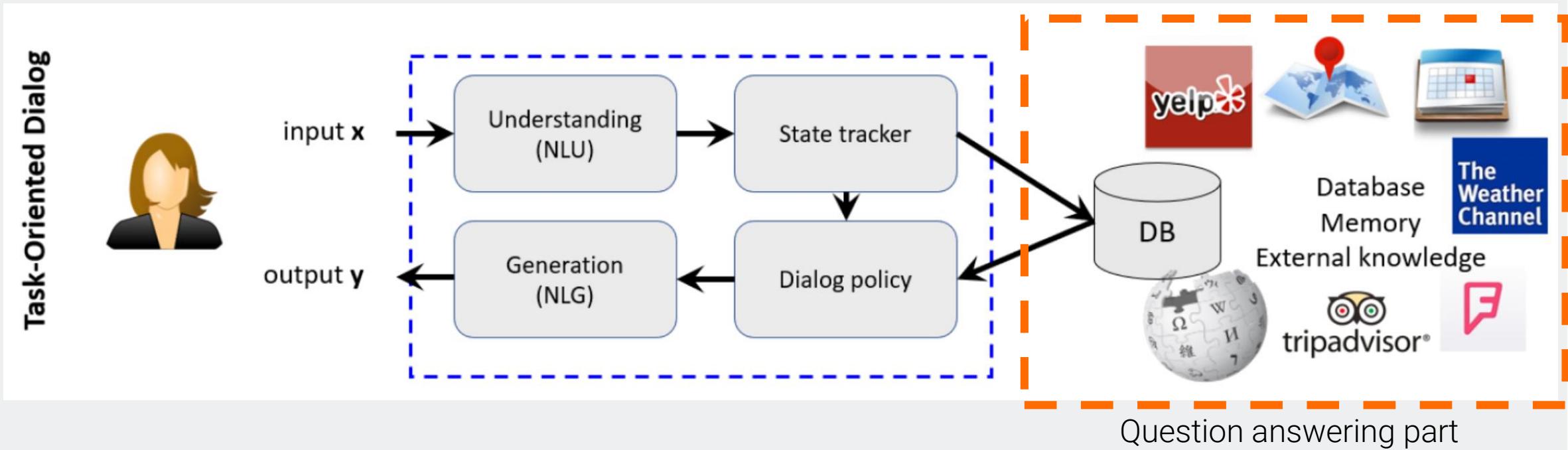


**Figure 23.15** An encoder-decoder semantic parser for translating a question to logical form, with a BERT pre-encoder followed by an encoder-decoder (biLSTM or Transformer).

# Classic Hybrid Approach: IBM Watson



# QA in the Common Agent Architecture



# Social Chat (Chatbots)

# Chatbot Architectures

- Rule-based
  - Pattern-action rules (Eliza)
- Corpus-based (from large chat corpus) – draw on QA system approaches
  - Information Retrieval
  - Neural network encoder-decoder

# Rogerian psychologist

- Draw the patient out by reflecting patient's statements back at them
- Rare type of conversation in which one can “assume the pose of knowing almost nothing of the real world”
- Example:
  - Patient: "I went for a long boat ride"
  - Psychiatrist: "Tell me about boats"
- You don't assume she didn't know what a boat is
- You assume she had some conversational goal
- Chatbots trying to pass the Turing test usually choose some such domain

# Eliza: Weizenbaum (1966)

Men are all alike.

IN WHAT WAY

They're always bugging us about something or other.

CAN YOU THINK OF A SPECIFIC EXAMPLE

Well, my boyfriend made me come here.

YOUR BOYFRIEND MADE YOU COME HERE

He says I'm depressed much of the time.

I AM SORRY TO HEAR YOU ARE DEPRESSED

...

WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU?

My father

YOUR FATHER

You are like my father in some ways.

**WHAT RESEMBLANCE DO YOU SEE**

You are not very aggressive but I think you don't want me to notice that.

**WHAT MAKES YOU THINK I AM NOT AGGRESSIVE**

You don't argue with me.

**WHY DO YOU THINK I DON'T ARGUE WITH YOU**

You are afraid of me.

**DOES IT PLEASE YOU TO BELIEVE I'M AFRAID OF YOU**

My father is afraid of everybody.

**WHAT ELSE COMES TO MIND WHEN YOU THINK OF YOUR FATHER**

Bullies.

**DOES THAT HAVE ANYTHING TO DO WITH THE FACT THAT YOUR BOYFRIEND MADE YOU COME HERE**

# Eliza pattern/transform rules

( 0 YOU 0 ME)      *[pattern]*

→

(WHAT MAKES YOU THINK I 3 YOU) *[transform]*

The 3 is the constituent # in pattern

You hate me

WHAT MAKES YOU THINK I HATE YOU

# Eliza Rules

keyword	pattern	Ranked list of transforms
	$(K \ ((D_1) \ (R_{1, 1}) \ (R_{1, 2}) \ \cdots \ (R_{1, m_1})))$	
	$((D_2) \ (R_{2, 1}) \ (R_{2, 2}) \ \cdots \ (R_{2, m_2}))$	
	$\vdots$	$\vdots$
	$((D_n) \ (R_{n, 1}) \ (R_{n, 2}) \ \cdots \ (R_{n, m_n})))$	

# Keywords are ranked from specific to general

I know everybody laughed at me

- “I” is a very general keyword:

I: (I \*) -> (You say you 2)

YOU SAY YOU KNOW EVERYBODY LAUGHED AT YOU

- “Everybody” is much more interesting (someone using universals like everybody/always is probably “referring to some quite specific event or person”)

WHO IN PARTICULAR ARE YOU THINKING OF?

- Implementation: keywords stored with their rank

**Everybody** 5 (*transformation rules*)

**I** 0 (*transformation rules*)

# If No Matching Keywords

Select a “neutral response”:

- PLEASE GO ON
- THAT'S VERY INTERESTING
- I SEE

Or use **Memory** (next slide)

# Memory

```
(MEMORY MY  
  (0 YOUR 0 = LETS DISCUSS FURTHER WHY YOUR 3)  
  (0 YOUR 0 = EARLIER YOU SAID YOUR 3)
```

- Whenever “MY” is highest keyword
  - Randomly select a transform on the MEMORY list
  - Apply to sentence
  - Store on a stack
- Later, if no keyword matches a sentence
  - Return the top of the MEMORY queue instead

# Other Eliza stuff

- Rules can refer to classes of words
  - Family = mother, father, brother, sister
  - NOUN = ...
- Don't reuse transforms in the same conversation
  - Whenever we use a transform associated with a pattern
  - We increment a counter for that rule
  - So the next time we use the next ranked transform
- Some basic transforms happen during input processing
  - I -> YOU
  - YOU -> I

# Corpus-based chatbots

Idea: Mine conversations of human chats or human-machine chats

- Microblogs: Twitter or Weibo (微博)
- Movie dialogs
- Cleverbot (Carpenter 2017 <http://www.cleverbot.com>)
- Microsoft Xiaoice
- Microsoft Tay

# A Cleverbot conversation

User:	Do you like Doctor Who?
Cleverbot:	Yes, so funny
User:	What's your favorite show?
Cleverbot:	I don't have one
User:	What's your name?
Cleverbot:	Jason I already told you.
User:	No your real name.
Cleverbot:	Stephanie IS my real name.
User:	I thought it was Jason?
Cleverbot:	How did you come to that conclusion.
User:	Because you said so.
Cleverbot:	I have to do my homework.

# Two IR-based chatbot architectures

## 1. Return the response to the most similar turn

- Take user's turn ( $q$ ) and find a (tf-idf) similar turn  $t$  in the corpus  $C$

$q = \text{"do you like Doctor Who"}$

$t = \text{"do you like Doctor Strangelove"}$

- Grab whatever the response was to  $t$

$$r = \text{response} \left( \operatorname{argmax}_{t \in C} \text{sim}(q, t) \right)$$

Yes, so funny

## 2. Return the most similar turn

$$r = \operatorname{argmax}_{t \in C} \text{sim}(q, t)$$

Do you like Doctor Strangelove

# Similarity functions

- Classic

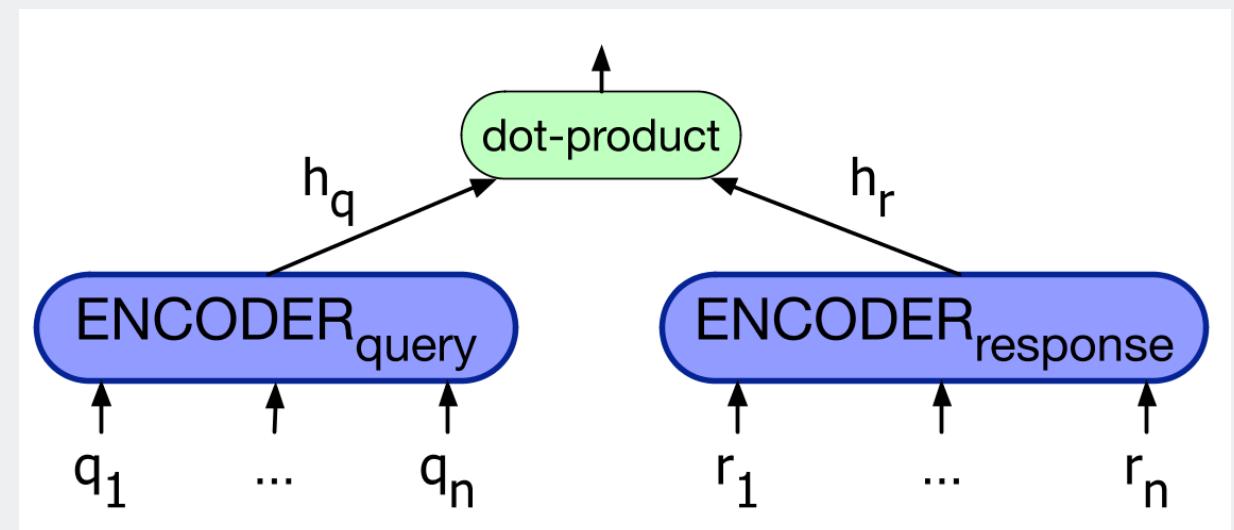
$$sim(q, r) = \frac{q^T r}{\|q\| \|r\|}$$

- Neural

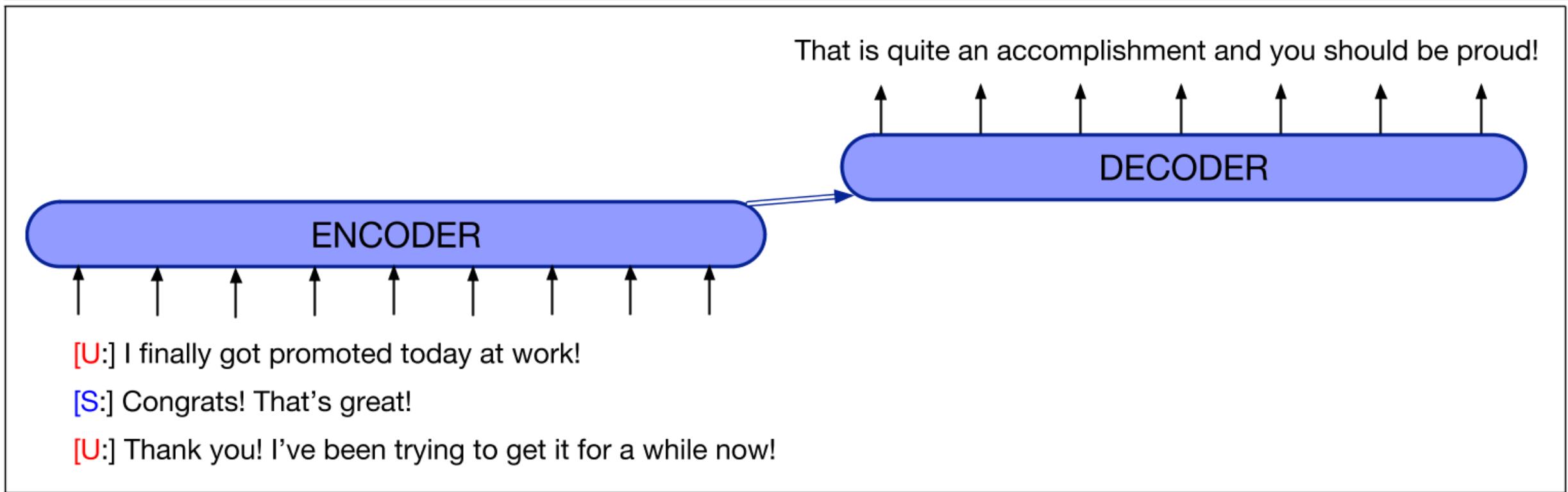
$$h_q = \text{BERT}_Q(q) [\text{CLS}]$$

$$h_r = \text{BERT}_R(r) [\text{CLS}]$$

$$sim(q, r) = h_q \cdot h_r$$



# Neural Network Architecture (Response by Generation)



# Chatbots: pro and con

- Pro:
  - Fun
  - Applications to counseling
  - Good for narrow, scriptable applications
- Cons:
  - They don't really understand
  - Rule-based chatbots are expensive and brittle
  - IR-based chatbots can only mirror training data
    - The case of Microsoft Tay
      - (or, Garbage-in, Garbage-out)
  - The future: combining chatbots with frame-based agents

# Evaluation

# Evaluation of Task Completion

## 1. Slot Error Rate for a Sentence

$$\frac{\text{\# of incorrectly-filled slots}}{\text{\# of total reference slots for sentence}}$$

## 2. End-to-end evaluation (Task Success)

# Task Completion Evaluation Example

“Make an appointment with Chris at 10:30 in Gates 104”

Slot	Filler
PERSON	Chris
TIME	11:30 a.m.
ROOM	Gates 104

**Slot error rate:** 1/3

**Task success:** At end, was the correct meeting added to the calendar?

# Common Evaluation Metrics for QA

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

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

# Dialog System Design: User-centered Design

Gould and Lewis 1985

1. Study the user and task
2. Build simulations - "Wizard of Oz study"
3. Iteratively test the design on users



# Ethical Aspects

# Ethical Issues in Dialog System Design

- Machine learning systems replicate biases that occurred in the training data.
- Microsoft's Tay chatbot
  - Went live on Twitter in 2016
  - Taken offline 16 hours later
- In that time it had started posting racial slurs, conspiracy theories, and personal attacks
  - Learned from user interactions (Neff and Nagy 2016)

# Ethical Issues in Dialog System Design: Privacy

- Agents may record sensitive data
  - (e.g. “Computer, turn on the lights [an-swers the phone –Hi, yes, my password is...”],
  - Which may then be used to train a seq2seq conversational model.
  - Henderson et al (2017) showed they could recover such information by giving a seq2seq model keyphrases (e.g., "password is")

# Summary



Servus! Wie kann ich helfen?

[Wie bekomme ich einen Kindergartenplatz?](#)

Für einen Platz im Kindergarten melden Sie Ihr Kind ein Jahr davor im November oder Dezember an. Spätestens Ende März erfahren Sie, ob und wo Ihr Kind einen Platz bekommt. Das Kindergartenjahr beginnt im September.

Anmeldung für einen Kindergarten der Stadt:

- Online
  - Schriftlich
  - Persönlich im Wunsch-Kindergarten
- [www.wien.gv.at/gogv/l9ahskindergarten](http://www.wien.gv.at/gogv/l9ahskindergarten)

Anmeldung für einen privaten Kindergarten

- direkt beim Wunsch-Kindergarten.
  - Voraussetzung ist eine Stadt Wien KundInnen-Nummer.
- [www.wien.gv.at/gogv/l9ahskindergartenprivat](http://www.wien.gv.at/gogv/l9ahskindergartenprivat)

Wenn Sie kurzfristig einen Platz brauchen, wenden Sie sich an das Infotelefon. Freie Plätze sind aber begrenzt.

Infotelefon Kindergarten und Hort

- +43 1 277 55 55  
 Mo bis Fr (werktags): 7:30 bis 18 Uhr  
 [post@ma10.wien.gv.at](mailto:post@ma10.wien.gv.at)  
 [www.wien.gv.at/kindergarten](http://www.wien.gv.at/kindergarten)

[Kindergarten](#)



WienBot Beta

[English Version](#)  
[Datenschutz](#)  
[Impressum](#)

Servus! Wie kann ich helfen?

Wann fährt die letzte U1 heute ab Karlsplatz?

Ich habe folgende Abfahrten gefunden:

Karlsplatz

**U1** Leopoldau  
Oberlaa

0 4 6  
3 8 13

# Summary

- Many applications of techniques seen in the course
- Commercial Dialogue Systems are often rule-based or have fixed dialogue structures (Finite State Dialogue)
- Never underestimate the power of rule-based approaches – can also be used to generate data for subsequent machine learning
- General purpose Dialogue Systems (task completion, QA, chitchat) are a current research topic